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Agriculture in Its Relations to Bacteria and Other Ferments.

BY H. W. WILEY,*

Chief of the Bureau of Chemistry, U. S. Department of Agriculture—Honorary Member of the Franklin Institute.

(*Concluded from p. 90.*)

Alinite has been subjected to extensive experiments by foreign chemists. For the practical use of the material it is mixed with water, and the infusion is applied to the seeds before they are sown. From 500 to 1,000 individual organisms are said to adhere to each seed. Many experiments with alinite have been made but the practical value of the substance is a question which must be left open for future experimental study. Theoretical considerations point to two conclusions: First, it seems logical to expect that if we plant with the seed large numbers of organisms, capable of rendering available the humus nitrogen already contained

*A lecture delivered before the Franklin Institute, Friday evening, November 1, 1901.

in the soil and endowed with the power of absorbing more nitrogen from the air, the young plants should begin their growth with a vigor and rapidity which would insure an abundant harvest. On the other hand, it must not be forgotten that bacteria in a favorable environment multiply with wonderful rapidity. Therefore, it seems that the good effects of this species of ferment would be more largely secured by establishing conditions favorable to their growth than by attempting to inoculate the soil with large numbers of them originally. In the present condition of our knowledge, therefore, it must be considered that alinite is of much more doubtful utility than nitrogin, and in both instances the future offers a problem of wonderful interest in connection with their study and development.

POSSIBLE SOURCES OF FUTURE NITROGEN.

From the above outline, it appears that the nitrogen on which the farmer of the future is to rely will be derived from various sources.

(1) The immense stores of nitrogen already existing, which Nature has stored up in ages past for the use of man, will continue to be one of the chief sources of supply for an indefinite time. These nitrates are found in caves and other protected places and in regions where the rainfall has not been sufficient to dissolve the products of nitrification as they have been formed. Vast areas are found in South America in which the soil is more or less saturated with these stored nitrates, among which nitrate of soda or Chile saltpeter is the most important.

(2) There will be those nitrogenous materials saved in fertilizers and applied directly to the fields.

(3) There will be the inorganic nitrogen which becomes fixed by electrical discharges and other chemical processes, and especially through the activity of certain micro-organisms living in symbiosis with leguminous plants.

(4) A possible source not yet determined, due to the activity of organisms not symbiotic, but capable of fixing nitrogen in a form fit for plant-food directly or through some intermediary not yet well known.

The advances in our knowledge of nitrification, and the organisms producing it, have developed new sources of scientific activity relating to agriculture. A study of the soils at the present time is incomplete without a thorough investigation of the character of the nitrogen which they contain and the nature and number of the nitrifying organisms active therein. Thus a new branch of agricultural research has been established.

For several years the Bureau of Chemistry of the Department of Agriculture has pursued studies of this description. From all parts of the country samples of soils have been secured, not merely for physical and chemical examination, but also for the purpose of studying the nature of the nitrifying organisms. To this end a new method of procedure had to be invented and tested. The problem of securing samples free from contamination with other organisms was one of considerable difficulty. This problem we have endeavored to solve in the manner described below.

Sterilized sampling tubes are prepared and covered with rubber caps as illustrated in the appended diagram. The tube is made of brass beveled at one end so as to easily enter the soil. The tube, rubber caps and the rubber balls, which are placed in them to prevent the cutting action of the edges of the tube, are subjected to a sterilizing temperature for an hour or two on three successive days. Any spores which may have escaped destruction in the first sterilization are permitted to develop and are destroyed in the successive sterilizations. The blunt end of the tube is filled with a plug of sterilized cotton, which serves to permit the egress of the air when the sharp end of the tube is forced into the soil to secure the sample.

In securing a sample, a ditch is dug of sufficient magnitude to easily hold the operator and to a depth of 3 or 4 feet. One side of this ditch is made as smooth as possible, and the points at which the samples are to be secured, beginning usually at 3 inches below the surface and continuing at stated intervals to the bottom, are marked. A platinum spatula, sterilized in the flame of an alcohol lamp, is used to remove the surface at the point where the sample

is to be obtained. Both rubber caps are then removed and the brass tube is forced with a turning movement into the soil so as to fill the interior with a core of the earth. The tube is withdrawn, the rubber caps restored and the whole enclosed in a mailing sack, which is then transmitted to the chemical laboratory for future examination.

The principal pieces of apparatus employed in this operation are shown in *Fig. 13*.

The samples, when they reach the laboratory, are used for seeding sterilized solutions containing nitrifiable nitrogen under standard conditions. The amount of nitrous and nitric acids produced by the seeding with different soils is measured from time to time and thus the comparative nitrifying power of the sample is determined. The respective quantities of nitrous and nitric acids are best shown in a graphic way as illustrated by the appended diagrams.

The figures in the vertical column show the parts per million of total nitrous and nitric acids produced.

The continuous black line indicates the total nitrification due to the sum of nitrous and nitric acids.

The dotted line shows the quantity of nitrous acid at any given moment.

The difference between the dotted line and continuous line at any point shows the excess of nitric acid over nitrous acid at any moment.

It is evident that the nitrous acid is first formed; after a short time the nitric acid begins to show itself, and at the end of the experiment the nitrous acid has practically all disappeared and the total acidity present is due to nitric acid.

It is evident that all studies of this kind in the beginning must be, to a certain extent, crude and imperfect, but they mark the path along which progress will be made and show a new departure in the study of soils, which should enable the agricultural chemist of the future to determine by experimental methods the power of a soil for nitrifying purposes.

In the study of the nitrifying organisms, as outlined in the foregoing address, I have had the valuable collaboration of my assistant, Mr. E. E. Ewell. With rare skill and

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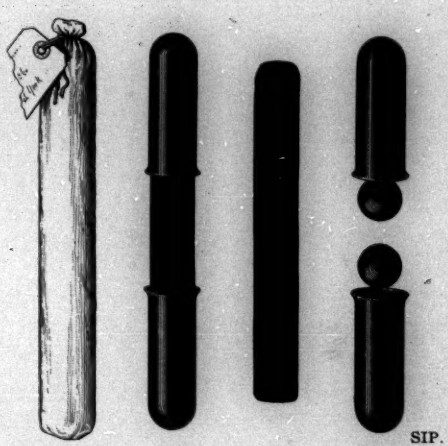

Sterilized tube for securing samples for nitrificative studies.

No. 1.—Brass tube.
No. 2.—Rubber caps and balls.
No. 3.—Tube sterilized and coppered.
No. 4.—Tube ready for shipment by mail.

RECORD OF THE PROGRESS OF NITRIFICATION IN CULTURES Nos. 301 and 301a

Sample No. 1.
Source of the sample, College Station, Texas
Kind of soil, virgin.
Date of taking the sample, April 20, 1895.

Serial No. 14186.
Depth below surface, 3 inches.
Vegetation growing thereon, native grasses
Date of sending cultures, May 3, 1895.

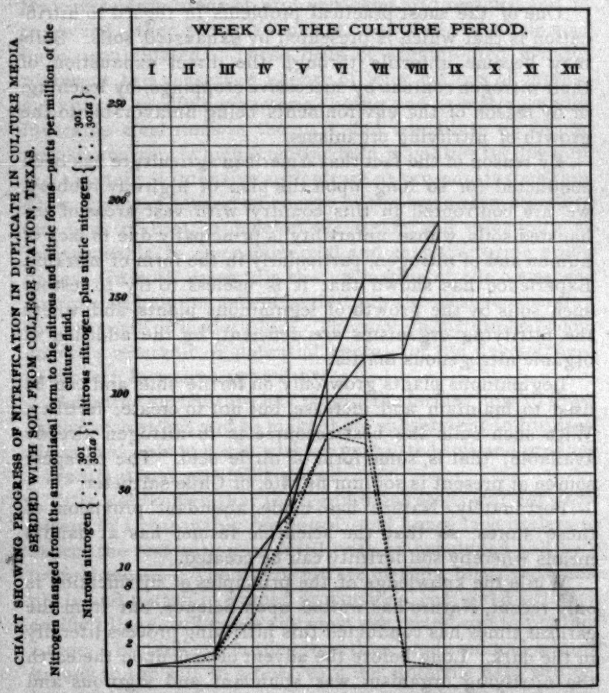
CHART SHOWING PROGRESS OF NITRIFICATION IN DUPLICATE IN CULTURE MEDIA SEEDED WITH SOIL FROM COLLEGE STATION, TEXAS.
Nitrogen changed from the ammoniacal form to the nitrous and nitric forms—parts per million of the culture fluid.
Nitrous nitrogen { . . . 301 . . . 301a } ; nitrous nitrogen plus nitric nitrogen { . . . 301 . . . 301a }
WEEK OF THE CULTURE PERIOD.
I II III IV V VI VII VIII IX X XI XII
250
200
150
100
50
10
8
6
4
2
0

patience and great industry he has worked out the details of the problems connected with the experimental work, and by his valuable and timely suggestions improved the methods and processes which were at first prescribed.

The foundations of a new research which have just been laid we hope may serve as a superstructure for future inves-

tigations which will develop and establish the very best possible methods for the study of soil ferments.

THE PROBLEM OF EXHAUSTED SOILS.

One of the most practical problems in regard to nitrification is that which is presented by exhausted soils. Soils may become unfertile through the direct exhaustion of their nitrogen content by successive croppings, by leaching, or by reason of the environments being unfavorable to the growth of nitrifying organisms.

By reason of the fact that American agriculture has been conducted for so long upon the plan of highway robbery, we are confronted in this country with vast areas of exhausted soils, whose unfertility is principally due to lack of humus and of nitrogen, particularly in the form of nitrates. Experience has shown that it is useless to try to restore such soils by the growth of leguminous plants, and, where the nitrifying organisms are deficient, by the addition of organic nitrogenous matter.

Leguminous plants grow only on fertile soils and can be used to maintain and increase, but not to create, fertility. With such soils the best recourse is to nitrogen already available; that is, some form of nitric acid. The cheapest source at present is sodium nitrate, or Chile saltpeter.

Fortunately, Nature has made abundant provision of these stores, so that the scientific farmer has at hand a means whereby soil fertility can be created.

While the knowledge of the principles of nitrification is only recent, Nature has waited upon Science, but from the earliest times has conducted this nitrifying process literally in the dark. Long before the advent of man upon the earth the nitrifying organism was abundant and vigorous and was plying its vocation without man's knowledge.

Wherever other conditions of nitrification existed, and the rainfall was deficient, the products of nitrification have accumulated, sometimes in enormous quantities, so as to form regular strata of nitrates. The most remarkable known case of this is the formation of the extensive beds of sodium nitrate in Chile, and to a limited extent in Egypt.

The nitric acid is combined with calcium in some cases, in others with potassium, and in the most extensive deposits it is combined with sodium to form sodium nitrate, which at present is the most important source of supply. It is thus that over large areas of arid and semi-arid regions, and in caves and other protected places, vast stores of nitric acid have accumulated. These beds of accumulated nitrates represent the conserved energy of long periods of intense activity of nitrifying bacteria, living and operating under favorable conditions in the past, and constitute an important source upon which scientific men may draw for developing a system of intensive agriculture at present, just as they draw upon the conserved energy of the sun's rays, stored in our beds of coal, to develop the steam and electricity so indispensable to our commercial and manufacturing enterprises. In both cases it is the utilization of the conserved energies of long periods of activity in the past for meeting the demands of modern life. The sodium nitrate beds constitute a reservoir of potential energy for the development of modern intensive agriculture.

Scientific agriculture has taught the farmer how to draw upon these stores and to make them subservient to his uses. He is thus able to begin with an exhausted soil and produce a luxuriant and profitable growth.

It is well known that the leguminous crops will not grow except in a reasonably fertile soil, and hence it is useless to expect the restoration of fertility to an exhausted soil by a natural means. The use of nitrate of soda, dissolved phosphate and potash in proper proportions, combined with scientific tillage, will cause the most exhausted soil to produce a crop. By plowing in the crops thus produced and adding humus to the soil, in a few years the unfertile field will become largely productive. In this manner, humus and other necessary ingredients are obtained and added to the soil, and the conditions of fertility are provided which will favor the growth and maintenance of leguminous and other crops and thus preserve and even increase the fertility produced.

We must regard, therefore, the natural deposits of nitrates, particularly those of sodium nitrate in Chile, as

one of the most important resources at the hand of the farmer for the rejuvenation of impoverished soils. This, however, is not the only use of natural nitrates; they are especially valuable for intensive culture in gardens and fields tributary to large cities where quickness and abundance of growth are factors of prime necessity. The ready-formed nitrate is an indispensable fertilizer for flowers and gardens as well as for fields. It performs a function which cannot be easily replaced by any other form of nitrogenous material among field crops. It has been demonstrated especially that the sugar-beet is an object to which the sodium nitrate can be directly and profitably applied, affording a more economic form of nitrogenous fertilizer than can be secured in any other way. The beet is only a type of many field crops demanding ready-formed nitrates in addition to the gardens and market-garden farms already described.

It appears, therefore, that advancing knowledge in agricultural chemistry, showing how organic nitrogen can be best assimilated, and in what manner inorganic nitrogen can be fixed and made ready for use by means of symbiotic organisms, only increases the means of carefully conserving and wisely using the natural deposits of nitrates already discovered. Advancing agriculture renders of greater interest the discovery of beds of nitrates yet unknown, whose treasures can be added to the assets of the scientific farmer.

To me, it seems that a wise use of the resources which Nature has placed at our disposal, together with a practical application of the principles of science, will serve to show how a properly managed soil can be increased in fertility instead of exhausted by continuous cropping, thus removing any fear of the fate of starvation.

The fields of the future, instead of becoming poorer will grow richer; the average yield of foods per acre will increase so that the coming increasing millions of the world's people will be better fed, better clothed and better taught than those that have gone before.

It is not the fear of starvation that confronts men in the remote future. If this planet, as is probable, is to live its

day and die as others have done, it will not be because of the exhaustion of the earth's supply of plant-food. The circuit of life is complete, and no item of matter which has once been available for plant-food can ever be hopelessly lost for the same purpose.

In the changes which come and go the vital molecule of matter will again live even it have been dead for thousands of years. Science and practice will add indefinitely to the stores of human food, and the scientific agriculture of the future years will be ready to feed the mouths which come into existence.

For every mouth, it must be remembered, Nature provides two hands. The capacity of the mouth remains constant while the ability of the hands to fabricate, to make and to earn is constantly increasing. The future, therefore, will bring more leisure, more ease, more culture and more food.

Should the races of men ever cease to exist upon the face of the earth, as is possible, it is evident to my mind that a cosmic and not any economic cause will bring about the result.

It seems more probable that the earth is gradually cooling. Paleontology finds evidence of tropical life, both plant and animal, far in the polar regions. It seems that all life is gradually approaching the equator. The armies of ice are slowly but surely advancing their lines, and the time may finally come when the last man will reach the equator. Far in the millions of years will this event take place. Dwarfed in stature, flat of head and hopeless of face will this last man be—the remnant of civilizations and of nations long extinct. Exhausted with his struggle for existence he will calmly and hopelessly await the end.

The future will not see the fulfillment of the prophecy of Berthelot when all men will be fed food formed in the chemist's crucible. The future will not see the fulfillment of the prophecy of Crookes when all men shall starve for the lack of wheat which farmers can no longer grow. Only a future too remote to be finite can possibly see the fulfillment of the prophecy which sees the end of humanity in a universe of ice.

AN IMPROVED FORM OF APPARATUS FOR PRODUCING THIN FILMS BY ELECTRO-DEPOSITION.

Herr Endruweit, of Berlin, has patented an improved form of apparatus for producing thin films by electro-deposition. An endless metal band is first coated with potassium sulphide, and, after washing, is passed through a nickel bath of the usual composition. The thin film of nickel obtained in this way is backed by copper (by passing through a similar bath containing a copper salt in solution) and by tough paper, before being stripped from its support. A strong sheet or roll of paper faced with bright metallic nickel can be obtained in this manner, and the use of this material after relief-stamping and coloring, for wall-papers and for advertisement show-cards is said to offer many advantages. The electro-deposited "paper" is also reported to be useful for packing the stuffing boxes of high-pressure steam engines, and, if sold at reasonable rates, it is possible that there are many uses for which it may prove suitable.—*Scientific American.*

TURQUOISES FROM RUINS.

The exhibits of the American Museum of Natural History will soon be enriched by a fine collection of turquoise objects obtained from the ancient ruins of New Mexico. The collection was brought in a few weeks ago, and contains many objects which are unique and of great scientific value, aside from their intrinsic worth.

Turquoise is essentially the American gem, not only in the sense that it is most highly valued by all the Indian tribes, as it has always been by their ancestors, even long before the days of Columbus, but also because within the past few years the American product has practically driven out of the market the Persian and other imported stones. An examination of the gems offered for sale by one of the leading jewelers on Union Square the other day showed ten American stones to every one that came from other countries, and demonstrated, moreover, that the home-product is superior in every way to the imported, especially in that peculiar blue color, which, like the "pigeon's blood red" of the ruby, gives the gem its value.—*Scient. Am. Suppl.*

MELTING SNOW BY STEAM.

The heavy snowstorms of last winter, which for several days blocked the enormous traffic of New York City, brought to light three curious machines employed by the Street Cleaning Department for the removal of snow. In general appearance these snow-melters resemble a road-roller without rollers. In place of the forward rollers is a large iron box, into which a dozen men shovel snow. Behind the box and extending to the rear end of the machine is a boiler, from which two funnel-shaped pipes about a foot in diameter extend into the box. Steam is forced from these pipes through jets into the box, and the snow melts as fast as it is dumped into the box. The water runs down into a sewer. In eleven hours one machine removed 750 yards of snow. Nine teams were able to do the work for which seventy-five were formerly required.—*Scientific American.*

THE FRANKLIN INSTITUTE.

Stated Meeting, held Wednesday, February 19, 1902.

President JOHN BIRKINBINE in the chair.

The Metric System of Weights and Measures.

(*Concluded from p. 120.*)

SOUTHWARK FOUNDRY AND MACHINE COMPANY.

PHILADELPHIA, February 4, 1902.

To the Secretary:

Your favor of the 26th ult. respecting the introduction of the metric system in the United States, and requesting our opinion as to the advisability of same, is received.

We are earnestly opposed to its introduction in our line of business, for we believe the present system of measurement is more convenient, and just as efficient in every way.

The writer was at one time connected with an establishment wherein the metric system was employed in one department and the English system in the rest of the works. It was his experience that foreigners who were used to the metric system, after learning our system, preferred to work with it rather than the metric in making drawings; in other words, preferred to work in the department using our present system, rather than in the department where they used the metric.

The writer spent some time abroad a few years ago, and found that for convenience, they used as few decimals as possible upon their drawings, as it was difficult in many places to find room for the figures, just as we try to avoid fractions containing too many figures for convenient insertion.

In addition to the above reasons, we desire to say that it would put us to a serious expense to change all our standards to comply in a practical way with the metric system; a sacrifice we do not feel, under the circumstances as explained above, we should be called upon to make.

Very truly yours,

SOUTHWARK FOUNDRY AND MACHINE COMPANY,

JAS. C. BROOKS, *President.*

To the Secretary:

The feasibility and advisability of the adoption of the metric system in the United States is not a new subject of discussion in this hall. The older members of the Institute will, no doubt, recall the fact that in 1876 a committee was appointed, to whom was referred a circular of the

Boston Society of Civil Engineers asking the co-operation of the Institute "in petitioning Congress to fix a date after which the metric weights and measures shall be the only legal standards."

Two reports were presented, the majority opposing the measure chiefly, I believe, on the ground of great cost and appalling confusion which would result to manufacturing industries by the substitution of the metric system for the standards in daily use.

The concluding words of the majority report were as follows:

"The Franklin Institute has never placed itself on record as opposing true progress; it has always advocated changes which were beneficial and not destructive. In this case, a majority of your committee believe that the ultimate benefits of the change proposed would be of less value than the damages during the transition. They think that the Government of the United States has already done all that can be fairly asked of it by the most enthusiastic advocates of the metrical system, by making it legal. Those of us who choose to do so can use that system, and no one can object to it; but for the Government to require us to use that, and no other, would be an arbitrary measure which we are neither willing nor able to bear. The majority of your committee are of opinion, and so report, that the objections to the attempt to adopt the *meter* as a standard unit of lineal measure are overwhelming, whether we consider the compulsory means proposed or the end to be attained.

"All of the objections to the metrical system do not apply to the adaptation of the decimal scale to our existing units. In the decimal harmony between the cubic foot and its content of water weighing 1,000 ounces avoirdupois, whereby a cube $\frac{1}{10}$ of a foot on the edge becomes the measure of the ounce of water, we have the means of constructing a decimal system of weights and measures which would interfere the least with existing institutions. But your committee do not feel called upon to consider this branch of the subject."

The minority report, while differing from the majority report in certain particulars, agreed with the conclusions of the majority of the committee, so far as related to the subject specifically referred to them, viz.: that "it is inexpedient to attempt at present to anticipate, by enactment, the time when this great step in the progress of human civilization and unity shall be taken by the National Government of the United States."

In the quarter of a century that has elapsed since this important subject was so ably discussed by the special committee of the Franklin Institute, manufacturing industries in this country have advanced to a marvelous degree, so that, instead of occupying a comparatively unimportant position in the markets of the world, they have forged to the front and have become dominant. This fact is of prime importance in

considering the advisability of the adoption of the metric system in the near future.

The members of the committee recently appointed to consider this subject are abundantly able to estimate the force of the objections raised by the majority of the committee of 1876 to the adoption, at that time, of the metric system, and, furthermore, it should be observed that the proposed resolutions do not contemplate an immediate compulsory substitution of the metric system of weights and measures as the sole standard in the United States, but that "the National Government should enact such laws as will ensure the adoption of the metric system of weights and measures as the sole standard in its various Departments as rapidly as may be consistent with the public service."

In conclusion, I may say that I am in favor of the resolutions.

ALEX. E. OUTERBRIDGE, JR.

PHILADELPHIA, February 12, 1902.

To the Secretary:

* * * The question of the adoption of the metric system by the United States may be regarded as having passed the academic stage, and as a purely practical one under present world conditions. Scientific men everywhere, recognizing the advantages of that system for record and computation, have not only settled the question for themselves, but have caused its incorporation by the more recent advanced applications of science, so that familiarity with it is becoming absolutely necessary to those concerned with such applications. For external commercial purposes on a large scale, it is becoming absolutely necessary for the United States to put it in complete touch with those nations which she most desires to reach in trade, which have generally adopted it. And, on the other hand, adoption by the United States would tend greatly to its early universal adoption. For internal purposes, the multitudinous minor retail transactions, whilst the transition from the present system, or rather want of system, might be attended with some inconvenience, this would be but temporary, and might in fact prove much less than might be anticipated with the American people, whilst the advantages would be permanent.

In reaching this conclusion any advantages of the metric system are not overestimated, nor its disadvantages overlooked. In many ordinary operations the question of record and computation are the least involved, whilst the arbitrary, unnatural, if you please, decimal division may lack convenience and adaptation in many of the minor transactions of the people. But the most practical question involved is not one of a standard and its divisions, but rather of uniformity of standard and its divisions as against a perplexing diversity of standards and divisions, often inexplicable and causing confusion and ambiguity even for experts, a

condition of affairs which all the time and labor and instruction in the schools, according to my experience with many of the best educated in them, can do practically little or nothing to relieve.

In this connection, it would seem that an advantage in the adoption of a radically new system, such as the metric, would be found in its freedom from further possible confusion, which any attempted recasting or adjustment of the present system would inevitably contain with the retention of old names and divisions. As to the names and divisions of the proposed system, they will rapidly adjust themselves to the masses, as those of the present currency have done, with the halves and quarters, and the suggested recoinage of the half-cent to make the eighth possible, whilst for accounts and computations all the advantages of the prevalent arithmetical notation.

Whether the decimal system is the best, whether the inconveniences and absolute losses occasioned by its adoption in some directions would be justifiable, and many questions of a similar character, are met by the unmistakable trend toward its universal adoption, that the United States, in its competition for external trade, would be compelled sooner or later to fall in with; so that, upon the whole, it cannot but be regarded as the wisest policy to inaugurate the change at the earliest date, and carry it out as rapidly as possible. Yours truly,

CHARLES F. HIMES.

CARLISLE, PA., February 18, 1902.

To the Secretary:

THE ENGLISH *versus* THE METRIC SYSTEM.

While the American Society of Mechanical Engineers is taking steps to prevent legislation by Congress for rendering the use of the metric system compulsory, the Franklin Institute in its meeting on February 19, 1902, has passed resolutions recommending such legislation. It can therefore not be considered as inopportune if at this date some further arguments on the main question thus at issue be presented, and in special such arguments which, although of fundamental importance, have never before been presented.

The claim of superior scientific merit in the metric system rests on the qualities of the system, as here below stated, namely:

(1) The metric system uses, in the division of distances and of matter, a system which is in absolute harmony with the arithmetical system conjointly used therewith. (Under the English system the division-system for distances is the duodecimal system in part, or only imperfectly carried out, and the arithmetical system is the decimal system, and the division of matter is neither duodecimal nor decimal nor is in disharmony with the rest of the English division-system.)

(2) The metric system involves the conditions for immediate conversion of volume into weight and *vice versa*, when density is known; because the weight-unit is that of a known volume-unit of water, the density of which is the unit of all other densities.

(In the English system the necessity exists of using, aside of the density-figures, in such conversion the weight of a volume-unit of water, such as lb. 0·036118 for a cubic inch.)

It does not appear that a change of our arithmetical system is advocated, except by those radical scientists who assert that no arithmetical system is rational, unless it is rooted in the powers of a product of 2 and 3, or of a multiple thereof, for many good and valid reasons, one of which is the discomplication of logarithmic values under such a system.

Therefore, it may be considered as altogether out of all discussion that we change from our decimal arithmetical system to the use of powers of 12, or to the duodecimal system. Then the issue is narrowed down to the problem of adapting the English division-system of distances and of matter to the decimal arithmetical system. If this should be found impracticable, then there is no resisting the full acknowledgment of the absolute superiority of the combined decimal and metrical systems.

It is the purpose of this, my present writing, to claim that such adaptation as mentioned is both possible and practicable.

A careful and critical investigation of all arguments advanced in favor of the English system of measuring distances and volumes reveals the fact that essentially they are arguments in favor of preserving the inch.

Why then should the English or thenceforth the American system of measuring distances and volumes not be improved by adopting the inch throughout as the unit? We may then reduce the new or American foot to 10 inches. We have then 1 rod 200 inches in place of 198, and make it 5 yards, or the yard 40 inches instead of 36 inches. And nothing prevents us even from dropping the terms yard and rod altogether and in speaking in the American system of ten-foot, hundred-foot and mil-foot measures.

While thus harmony be created between division-system and arithmetical system in our own American system—the interconversion between volume and weight, that great virtue of the metric system, still remains unattended to.

It cannot be said that such conversion-possibility be of less importance to the mechanical engineer than to the civil engineer, both professions meeting with the frequent necessity of determining weight by a known volume.

To restore harmony under the American system between the method of interconversion and division, we have to start from the same unit, namely the *inch* or *cubic inch*. In present pounds the cubic inch of water, at its highest density, weighs 0·036118 pound. Assuming 3,611·8

pounds to be made the equivalent of 4,000 new or American pounds, and such to be made the standard bi-ton, the equivalent of a volume of 100,000 cubic inches of water, the American ton would weigh 2,000 pounds new or American weight, or 1,805·9 pounds of old weight, and be the weight of 50,000 cubic inches of water at highest density, or at a temperature of 39° F. Therefore, by the reduction of our present pound to 3611·8/4000 of its weight to become the new American pound, such American pound would have the precise weight of 25 cubic inches of water.

This leads to the conclusion that there should be a new weight unit of an American bi-kilo or the equivalent of 4 American pounds weighing as much as 100 cubic inches of water. A cube of 10 inches or of 1 American foot of water then would weigh 10 bi-kilos.

One of the characteristic and advantageous features of such adaptation of the American system, the same as of the metric system, to intra-conversion of weight and volume deserves special attention, namely the facile handling of all calculations of mechanical resistance and equivalent power in continuous action, such as, for instance, of an impinging water-jet. The general equation reads:

$$H\text{-}P = \frac{(F.v).\frac{v^2}{2g}}{s} \quad \text{or} \quad \frac{F.v^3}{s.2g}$$

F indicating the transverse section of the impinging jet, on condition that a column of such jet 1 foot long shall weigh 1 pound.

s indicating the foot-pound equivalent per horse-power second, under the prevailing system = 550, but under the proposed American system as 550 . 1·2 . 4/3·6118 = 731, the values v and g being used as in general acceptance;

$$g \text{ becoming} = 32{\cdot}183669 \times 12/10 = 38{\cdot}62.$$

According to the valuation of the foot and of the pound under the proposed American system, a column of 1 American foot or of 10 inches length weighs 0·4 American pounds if it has a base of 1^2 inch, hence in order to weigh 1 American pound, its base or its transverse uniform section must be as 1^2 inch /0·4 = 2·5 square inches.

Assuming a 54-foot velocity under a 52-foot head and a circular orifice of ejection of 2 inches diameter or of 3·1416 square inches.

(*a*) By $\frac{3{\cdot}1416}{2{\cdot}5} = 1{\cdot}25664 = F$, and

(*b*) By $H\text{-}P = \frac{1{\cdot}25664 \cdot 54^3}{731 \cdot 2 \cdot 38{\cdot}62} = 3{\cdot}5$ *H-P.*

This must of necessity appear as less than calculation with feet of 12 inches in place of 10 inches would show, because the reduction operates at the cube of velocity, by $10^3/12^3 = 0{\cdot}579$.

And to the meritorious feature, thus demonstrated, of the adaptation rather of our present fundamental unit of measurement—the inch—to the inter-conversion or metric system, in preference to its abolition, I may show a further addition by mentioning that by substituting, instead of F, and expressed in the same units of 2·5 square inches, the value B/d, or properly the value $B/(d \cdot 2{\cdot}5)$; B being the weight in American (new) pounds of the water displaced by the ship in its immersion—and d being the lenght of the ship in the direction of its motion on the water-line—the mathematically provable resistance to ship's motion and the power required for such motion may be calculated precisely. The proof of such equation rests on the consideration of the serial positions of ship in repeated lengths of its own (as if in ice), and of the fact that quantities not so indicated as displaced, reoccupy (in quantity, though not in identity) former position, as well as on the actual demonstration that not friction but volume and its form are the conditions for resistance by the medium, subject to the coefficient of density of the medium, which for water is as 1. (Compare this *Journal*, 1893, Nos. 3–5.)

F. M. F. CAZIN.

HOBOKEN, N. J., March 12, 1902.

AMERICAN WALTHAM WATCH COMPANY.

WALTHAM, MASS., February 5, 1902.

To the Secretary:

We are in receipt of your communication of 1st inst., together with the report of your committee, who have had under consideration the merits of the metric system of measures. * * * We desire to say that we agree with the conclusions of your committee in every one of the questions specified. We may say that for more than thirty years we have employed the metric system of linear measurement as being greatly superior in convenience for the minute measurements required in the manufacture of watches. In adopting this system we took a centimeter as our unit of measurement. This we subdivide into a thousand parts, and have special gauges reading to thousandths. In many instances we subdivide by the eye the graduations on our gauges. Having this system in use for measurement of watch parts, we also use it in our machine department in the manufacture of machines, and while it is somewhat novel to men when they first come to us, yet they very readily acquire the system, which is extremely simple in computation.

We trust that the deliberation of your society will in some measure hasten the adoption of this system as a Government standard of measurements.

Yours truly,

AMERICAN WALTHAM WATCH COMPANY.

E. A. MARSH, *Gen'l Supt.*

BAUSCH & LOMB OPTICAL CO.

ROCHESTER, N. Y., February 18, 1902.

To the Secretary:

Replying to your favor of the 15th inst., we wish to express ourselves as heartily in favor of any plan which will hasten the adoption of the metric system in this country. We have used the system in our workshop for a number of years, as its units are much more convenient, especially in the fine measurements required in our class of work. We have also published our catalogues of scientific apparatus wholly in the metric system for a number of years, and find that this departure is very much appreciated by the scientific men with whom we deal. There is, however, a great disadvantage from a business standpoint in having two systems in use in this country. For example, we are requested to bid on chemicals by weight. We hand in our estimate based on quantities of 500 grams. A competitor hands in a bid on similar articles based on quantities of 1 pound. The average man does not stop to consider that there is a material difference in weight between 500 grams and 1 pound. We are, therefore, placed at a disadvantage, as our prices appear to be higher than those of our competitor, although they may in reality be lower, gram for gram.

The use of the two systems in periodical literature makes it absolutely necessary for those desiring to make any use of the investigations of others to be perfectly familiar with the equivalents of the two systems, and able to carry in his mind the value of inches and fractions of inches in millimeters, and *vice versa*, a wholly needless and time-consuming operation.

As it is without doubt only a matter of a comparatively short time when the principal nations will adopt the metric standard, it would seem to be to the utmost advantage of the United States to hasten the day by every possible means. Yours truly,

BAUSCH & LOMB OPTICAL CO.

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

To the Secretary:

* * * In the matter of the metric system, and your circular covering the questions discussed January 17, 1902, the points where I should take issue with the decisions of the committee would be the replies to 3, 6, 7 and 9.

In answer to Question 3, I would say that there are many more valid objections than the one presented in that question. The meter is too large as a unit and a millimeter is too small for uses in the average manufacturing process. The use of the decimal point on drawings and the use of dimensions expressed in decimals is exceedingly inconven-

ient. The scale of drawings using the metric system is much less convenient than the scales which are derivable from our present units. My answer therefore to Question 3 would be "Yes" instead of "No." With respect to the fourth question, it does not appear to me that any objections but the one urged in No. 3 is affected by it. The additional objections which I have urged above, and which are not inclusive of everything that could be urged, are not affected.

Question 6 begs the question at issue. This question is the existence of the expense and confusion it would entail upon manufacturers. Granting that the answer to Question 3 is not what the circular implies, the recommendation of the change as a compulsory matter would not be desirable for the reasons that I have advanced and others.

In Question 7, if it were not the case that some people thought the change desirable, it would be without meaning to have the National Government enter the thin edge of the wedge. There is much productive business in the country bearing no relation to the general Government, and those establishments which catered to or supplied both the Government and general public would be put to the expense of carrying everything in double standard.

The Navy Department, for instance, has certain standards of its own in certain lines, which must be conformed to by those who supply the Navy, but which are without meaning to other concerns working for a different set of patrons.

It does not appear to me that the adoption of the governmental departments of the metric and decimal standard would necessarily carry with it its adoption within a reasonable time, without legislation to compel it. It is the objections to compulsory legislation in the matter which constitute the objection to the whole principle of forcing an inconvenient unit. The metric decimal system is already legitimized and anybody can use it who wants to. The object of legislation is to compel people to use it who don't want to do so without a pressure coming upon one end of their business interests. It is true that a large number of computations would be facilitated by the use of a decimal system, but it is a pity to force the advantages of decimal methods at the expense of the compulsion of the use of the inconvenient metric unit as a feature of that alteration. Very truly,

F. R. HUTTON,
Professor Mechanical Engineering,
Columbia University.

NEW YORK, February 13, 1902.

THE PENNSYLVANIA RAILROAD COMPANY.

PHILADELPHIA, February 10, 1902.

To the Secretary:

* * * In giving my views I would state that I am heartily in accord with adopting the metric system of weights and measures in the United

States. I do not believe it would create any embarrassment, and certainly would be a great benefit. The comparison between our present system and the metric system is about equal to dollars and cents as compared with shillings and pence, and I will therefore remember to vote to approve of any movement which will promote the universal introduction of the metric system, to take effect in the shortest possible time that will create the least confusion and expense. I do not see that it is necessary to defer the matter from any standpoint within my range of experience and knowledge. Respectfully,

JOSEPH T. RICHARDS, *Engineer, M. W.*

PENNSYLVANIA RAILROAD COMPANY, BROAD STREET STATION.

To the Secretary:

In response to yours of the 7th, I have carefully read the report dated January 22, 1902, of the special committee of the Franklin Institute relating to the metric system, and think that the committee has stated the case in a very conservative way. The subject is such a comprehensive one that I cannot well enter into a discussion of it by letter. I think, however, that the Franklin Institute should put itself upon record by the adoption of the resolutions suggested by the report of the committee above referred to. Yours truly,

THEO. N. ELY,

PHILADELPHIA, February 18, 1902.

R. D. WOOD & CO.

PHILADELPHIA, February 4, 1902.

To the Secretary:

Referring to your circular letter of the 1st inst., we agree heartily with the report of the special committee of the Franklin Institute of the advisability of adopting the metric system of weights and measures in the United States.

It would be most satisfactory to have the National Government make the metric system the only legal system throughout the United States, provided that sufficient time, say five or ten years, were given before it became compulsory, so as to permit of the different trades adjusting themselves to it. Yours very truly,

R. D. WOOD & CO.

FERRACUTE MACHINE COMPANY.

BRIDGETON, N. J., February 17, 1902.

To the Secretary:

The writer must confess that he is "on the fence," so to speak, in regard to the metric system. He fully appreciates the principal reasons

for adopting it, which are its systematic arrangement, and the facility it gives for easy computation; also the fact that many other nations are adopting it, and he thoroughly believes in international unity in all directions.

The principal reason against the metric system is that it is founded upon the abominable base of ten, and it seems to the writer that the world is progressing so fast now that possibly within this century we shall be able to start the only decent and proper base for all numerical work, sixteen. On this the whole world could found an entirely new system of weights and measures, which would be entirely permanent. A change of this kind would probably not be so difficult to make (if taught for a few years in the schools along with the old system) as many people may imagine. When we get it we will save an enormous deal of figuring, and have a really scientific system; and it is bound to come some time. Shall we wait? Yours very truly,

FERRACUTE MACHINE COMPANY,
per OBERLIN SMITH, *President.*

NEW YORK SHIPBUILDING COMPANY.

CAMDEN, N. J., February 18, 1902.

To the Secretary:

I regret to advise you that I have not read the report of the special committee on the metric system, which will be laid before the Institute on the 19th, and do not know just what is proposed. Under the circumstances I do not see that I can well render an opinion, excepting to state that no resolution of the Franklin Institute or any other such organization will bring about the use of the metric system. The ones particularly affected are the manufacturers, whose standards are all prepared under the duodecimal system; any change to a decimal system would mean to such manufacturers a very great confusion for a number of years, and while I am sure every one would be pleased if all our measures were under the metric system, it becomes a financial question rather than a theoretical one.

I have serious doubts as to whether the manufacturers are suffering sufficiently under the duodecimal system to care to encourage the expense of the change. I do not express this as a final view, but without serious consideration and without knowing exactly of what you purpose. Very truly yours, HENRY G. MORSE, *President.*

THE LINK-BELT ENGINEERING COMPANY.

NICETOWN, PHILA., March 19, 1902.

To the Secretary:

We have gone over the report of the special committee on the metric system with care and wish to most heartily endorse the con-

clusions arrived at. We consider it of the utmost importance that the inevitable change to the metric system be inaugurated at as early a date as possible, and adverse opinion seems to be of no value whatsoever. The advantages to be derived from the metric system's adoption are clearly manifest, and opposition to a movement of this kind would seem futile, as, at best, it can only mean a trifling postponement and not, in any way, prevent its ultimate adoption.

Yours very truly,

THE LINK-BELT ENGINEERING COMPANY,

J. M. DODGE, *President.*

LIBRARY BUREAU.

BOSTON, August 12, 1901.

To the Committee of the Franklin Institute on the Metric System:

* * * We have been interested in the introduction of the metric system since 1876, Mr. Dewey, the former president of the Library Bureau, having been president of the Metric Bureau, established in 1876, which has been given up because of lack of financial support. We have continued to use the metric system from the beginning of our manufacturing, not only because theoretically we believe it to be superior, but in practice a very decided economy; *e. g.*, in a comparison of weights and sizes of different thicknesses and grades of paper-stock we make them minutely as against long series of figures in the English. In our woodworking our men work to a closer degree of accuracy with no difficulty. Altogether we have continued to use the metric system in all our manufacturing because we find it is a direct saving.

Very truly yours,

H. E. DAVIDSON,

President.

BULLOCK ELECTRIC MANUFACTURING COMPANY.

CINCINNATI, O.

To the Secretary:

I beg to acknowledge your circular letter of the 1st, calling our attention to the report of the special committee appointed to consider the feasibility and advisability of adopting the metric system of weights and measures in the United States.

While we fully agree with the replies to the questions as shown by appendix attached to the committee's report, we would prefer that this change not be insisted upon for at least a year or two hence, and presume that even though favorable action should be taken at this time, it would be at least two or three years before it would come generally into use.

There is no doubt but what there would be many advantages in having the system a standard of this country, and there is no doubt also but what the change from the present system of weights and measures would involve the manufacturing concerns in very large expense. When it is decided to make the change, notice should be sent to manufacturers as far in advance as possible to enable them to prepare for these changes. More or less confusion is bound to develop in making the change, but this cannot be avoided.

We will be pleased to be kept advised in regard to the progress made, and beg to remain,

Yours very truly,

FRANK G. BOLLES,
Manager Advance Department, Bullock Electric Manufacturing Company.

J. A. FAY & EGAN COMPANY.

CINCINNATI, February 7, 1902.

To the Secretary:

Your circular letter of the 1st inst. we have at hand and noted. We have carefully reviewed the questions discussed at the meeting of your subcommittee of January 17, 1902, and it leads us to express ourselves as being exactly in accordance with the answers that were agreed upon at that time, with the exception of Question 8. We believe there would be serious confusion in changing from one system to another in a shop or institution as large as ours, unless the bulk of the tools were discarded and the changes made all at once. We would have to use both standards for a long time to come, because of the vast amount of repairs that it is necessary for us to furnish repeatedly for machines that have been in existence for a good many years. Still, we probably would not let this matter stop us from adopting the metric system provided it was to be recommended and put into practice. * * *

Yours truly,

J. A. FAY & EGAN COMPANY.

WILLIAMS, BROWN & EARLE.

PHILADELPHIA, February 4, 1902.

To the Secretary:

In reply to your favor of the 1st inst., we would state that we entirely approve of the resolutions proposed by the special committee, "that the metric system of weights and measures should be adopted by the United States Government as the sole standard in its various departments at as early date as possible." It seems strange that the United States, one of the most progressive of nations, should be so late in the adoption of the metric system as a measure of weights and lengths.

The longer such a change is deferred the more difficult and expensive becomes its adoption; we, therefore, should thoroughly approve of the United States Government initiating an early movement so as to make the change without interfering with the public service.

Yours respectfully,

WILLIAMS, BROWN & EARLE.

GOULD & EBERHARDT.

NEWARK, N. J., February 10, 1902.

The Franklin Institute:

* * * Relative to the matter of the metric system, we beg to say that we believe it would be a very good thing if some standard system of weights and measures similar to this could be adopted and universally used among all civilized countries; but so far as making its use compulsory, we think it will be a long time before this will be possible, on account of the great amount of money already invested in tools, instruments, etc., which are graduated by our present system. We think, however, the time is coming, but it means slow work, and the public will have to be gradually educated up to it.

Yours very truly,

GOULD & EBERHARDT,

FRED. L. EBERHARDT.

STANLEY ELECTRIC MANUFACTURING COMPANY.

PITTSFIELD, MASS., February 10, 1902.

To the Secretary:

* * * We agree with the resolves of the Institute and approve any movement which will permit the uniform introduction of the metric system, and we believe that the National Government should enact such laws as will ensure the adoption of the metric system of weights and measures in its various Departments.

Yours respectfully,

STANLEY ELECTRIC MFG. CO.,

R. W. POWER, M.E.

To the Secretary:

* * * No scientific man should be lukewarm in advocating the adoption of the metric system of weights and measures, and I think that any business man who should set himself seriously at work to estimate the time lost by the employment of the English measures where the French system could be used, would become inevitably an ardent advocate of a change to the metric system. * * * The English system is greatly supported by the rule of thumb. The best

examples of this method is that employed by the average photographer, who mixes his solutions by means of complex quantities approximately expressed in avoirdupois or troy weights.

Very truly,

JOHN TROWBRIDGE.

CAMBRIDGE, MASS., February 27, 1902.

THE AMERICAN JOURNAL OF SCIENCE.

NEW HAVEN, CONN., February 8, 1902.

To the Secretary:

To my regret I cannot be present at the meeting to be held at the Franklin Institute on the 19th, nor can I attempt to give my views in detail on the introduction of the metric system. I take pleasure, however, in expressing my most hearty sympathy with this movement and my endorsement of the report of the sub-committee as given on the enclosed sheet.

Very truly yours,

E. S. DANA.

THE MORGAN LABORATORY OF PHYSICS, UNIVERSITY OF PA.

PHILADELPHIA, February 6, 1902.

To the Secretary:

I am in receipt of the report of your committee on the subject of the metric system. * * * I endorse the report in every detail.

Respectfully yours,

ARTHUR W. GOODSPEED.

BROOKLYN, N. Y., December 16, 1901.

The Committee of the Franklin Institute on the Metric System:

In reply to your favor of December 13, I understand that you have a copy of my paper read at the meeting of the A. S. M. E. I have no other paper that I could furnish you.

There was no further discussion on this subject, which I regretted at the time, as I had hoped that the question of either adopting the metric system or some other decimal system—it makes little difference to me which—would be taken up and discussed, and that this might bring us a little nearer towards the desired end.

The system which was the object of my paper was, of course, merely a suggestion or a query as to the advisability of recommending same, being convinced that the adoption of the metric system, on account of its incommensurate relation to the English yard, will present almost insurmountable difficulties. Most of our tools, jigs, gages, etc., would have to be changed at an enormous expense, as it would not be practical

to adhere to the dimensions we are now using and express them in ten-thousandths of millimeters.

The ease with which values in the proposed system could be converted into values of the metric system would enable the two to exist side by side without interfering with each other.

Anybody will admit that our present system of measuring solids and weights should be revised anyway, and although I added the "vol" and the "pon" in order to make the system complete, I am in favor of adopting the liter and the kilogram in any case.

I was very glad to hear that the Franklin Institute had taken up this matter and I express the hope that something definite will be decided by your committee. If nothing else can be settled upon, let us have the metric system by all means, for the longer we wait the harder it will be for all of us later on. Yours truly,

F. F. NICKEL.

To the Secretary:

* * * I hope sincerely that the report of the special committee on the adoption by the United States of the metric system will be carried, as it is directly in the line of progress, and will prove as great an improvement as our decimal system of money is over the English currency.

ISAAC NORRIS.

PHILADELPHIA, February 7, 1902.

RUMFORD FALLS POWER COMPANY.

RUMFORD FALLS, MAINE, March 11, 1902.

To the Secretary:

Noting in our March JOURNAL the report of the special committee on the metric system, I am prompted to write that recently I enquired of my children if it was taught to them in the schools, and they did not even know what the system was. I then enquired of our Superintendent of Schools, and he replied that the tables were included in the text-books among other tables of weights and measures, but as the system is not in popular use, it probably received less attention in the classes than even its relative and small proportion of treatment in the text-books. He said also he found little about it in the educational press as a live educational subject. Does not this suggest two neglected opportunities, elementary and fundamental ones, for teaching and increasing the use of the metric system, viz.: First, getting the text-book writers and publishers to give it a larger place; and, second, to publishing more about it in the popular teachers' papers of every grade? I find that many are almost ignorant of the system; they regard it as something foreign; anyway, it is not familiar. I have sent to our

Superintendent my chart, issued by the American Metrological Society, which I regard as excellent. Please refer this to some one of the special committee of the Institute, or use it otherwise as may best help advance the use of the metric system. Yours very truly,

CHAS. A. MIXER,
Res. Eng.

ENGINEERS' AND ARCHITECTS' CLUB OF LOUISVILLE.

LOUISVILLE, KY., December 21, 1901.

To the Secretary:

I respectfully request that you use this writing as authority for casting my vote strongly in favor of the metric system of weights and measures. I would make it compulsory and in force as early as possible.

Yours truly,

THOMAS P. SHANKS.

PHILADELPHIA, February 7, 1902.

To the Secretary:

* * * I am in sympathy with the resolutions, and indorse the same. Yours very truly,

HORACE PETTIT.

Messrs. the Franklin Institute, Philadelphia, U.S.A.

SIRS:—I just received the February 21st number of London *Engineering*, and noted with the greatest interest that your Institute took so decisive a step in relation to the introduction of the metric system into your great republic, which we Dutchmen can never forget is the birthplace of John Lothrop Motley, to whom we owe so great a debt.

I am glad to see that the name of the great Franklin will be united to the great scheme of introducing the metric system and supplanting the barbarous, incoherent mass of weights and measures which is now prevalent in Anglo-Saxon regions. I am sure that if he had lived to-day, he would have been the first to propose the measure you have just taken.

What especially rejoices me is that not only scientific men like Mr. Jesse Pawling, Jr., signed the report issued by the committee, but that practical men like James Christie and others, joined in the recommendation of the metric system. Scientists, as physicians, chemists, have, even in Great Britain, adopted metric measures and weights, and so I was not at all astonished to see their names. But every technical man must feel what heavy expenses and great trouble will accompany the introduction of metric measuring into shop-work. The more it is to be appreciated that practical men join in the demand, but I am sure that after a purgatory of confusion the reward will not remain behind.

The cry for the metric system has been heard in Great Britain as well as in the United States, and I am glad to add that there also the cry is heard not only from scientists or laboratory workers, but also from practical men like Harvard Biles, Archibald Denny, etc.

Allow me, gentlemen, one little remark in relation to Questions 8 and 9 of the Appendix to the Report. There will be, of course, a little confusion accompanying the introduction of the metric system; but I beg to remark that the sooner the introduction is carried on, the less will be the confusion. There is now a whole stock of machinery, etc., which in time wants repair; bolts and nuts, boiler plates, wheel-tires, and so on, want periodical renewing, and in the majority of cases the articles dimensioned in feet and inches cannot be supplanted by metrically dimensioned ones. So, as long as this stock is not yet exhausted, a double set of lathes, of rules and regulations will be necessary; double sets of rolls for sections will be necessary for steel works for rolling the old and new sections. But this already large stock is daily rapidly increasing, and that is, in my opinion, the reason that, if it will be resolved to introduce the metric system, the sooner it will be done the better. Besides that, I think that for your foreign trade the time will not be far that manufacturers will be st with paatt,to accepmpelleod c their export business, the metric system, as otherwise they cannot take up the competition against German, Swiss and French manufacturers.

I beg to call your attention to the splendid work the Germans have already done with their book for sections, "Deutsches Normalprofil-Buch für Walzeisen," and also the work done in standardizing screw-threads, the "Internationales Gewindesystem," based upon the metric system, unites the advantages of the best two other systems—the Whitworth and the Sellers.

In expressing my best sympathy for the measure you have taken and the hope that it will soon bear fruit, I conclude by calling myself,

Most respectfully yours,

H. VAN MEERTEN, M. I. N. A.,

Late Chief Constructor, Dutch Navy.

BUITENZORG (JAVA), March 20, 1902.

P. S.—Before finally concluding, I beg to call your attention to the C. G. S. system, which has already done so much good service in the electric work, and which now Mr. A. Hauser, late Chief Constructor of the French Navy, has proposed for the standard to be used in ship building and machine building. His views are published as well in the Bulletin of the Association Technique Maritime as in the Transactions of the Institution of Naval Architects, and, if accepted, will in future considerably facilitate the study and working out of mechanical problems. * * *

H. VAN M.

THE DECIMAL ASSOCIATION.

BOTOLPH HOUSE, EASTCHEAP,

LONDON, E. C., February 14, 1902.

To the Secretary:

* * * I hail with gratification your attempt to make the advantages of the metric weights and measures known in the United States.

I will not burden you with a long narrative of the progress of the movement in England in favor of the adoption of the metric weights and measures. I may summarize the growth of strength of that movement in the fact that we can now count upon the support of 260 Members of Parliament, absolutely pledged to vote in favor of our object, whereas three years ago the result of a strong canvass only showed ninety-six whose favorable vote could be counted upon.

Barely a month passes but what some of our consuls abroad draw attention in their official reports to the loss of trade which we are suffering because our weights and measures are not understood in most of the continental countries. Sixty per cent. of our foreign trade (excluding British possessions) is carried on with countries which use the metric weights and measures. Yours faithfully,

E. JOHNSON, *Secretary.*

VICTORIA WORKS.

RUGBY, February 17, 1902.

To the Secretary of the Decimal Association, Botolph House, Eastcheap, London, E.C.:

DEAR SIR:—In reply to yours of February 14th, we should be much obliged if you would convey to the Franklin Institute, of Philadelphia, U.S.A., the following by way of communication from us on the subject in question:

We have carefully considered the questions asked for in the Appendix, and can fully subscribe to the answers agreed upon.

The suggestion made in Question 8 that existing tools and gages can be retained, and can be used concurrently with those designed to the metric units, is precisely the system we have followed for the last nine or ten years without the least difficulty whatsoever, notwithstanding the fact that, owing to our special circumstances, tools and gages to English units are still in use and that without creating any confusion. We have, therefore, no misgivings as to the soundness of the views expressed in Question 8. Yours faithfully,

WILLANS & ROBINSON, Limited.

HECLA WORKS.

SHEFFIELD, February 17, 1902.

To the Secretary:

* * * We thoroughly agree that the adoption of the metric system would be a great saving in time and money. * * *

Yours faithfully,

R. A. HADFIELD.

THE WALDORF-ASTORIA.

NEW YORK, May 10, 1902.

To the Committee of the Franklin Institute on the Metric System.

GENTLEMEN:—I thank you for your letter of the 26th April with enclosure—resolutions and report of the Franklin Institute approving of the adoption of the French metrical system. I am very glad that the Franklin Institute has given the weight of its support to the reform which seems now imminent. It will, I believe, be most beneficial to America, and its adoption here will, I am sure, be very effective in accelerating its adoption in Great Britain and the British Colonies.

I remain, yours faithfully,

KELVIN.

COMMITTEE ON COINAGE, WEIGHTS AND MEASURES.

House of Representatives, U. S.

WASHINGTON, D. C., February 24, 1902.

To the Secretary:

I desire to thank you for your letter of February 24th, containing information that at a stated meeting of the Franklin Institute, held Wednesday, February 19, 1902, the report of the special committee appointed to consider the feasibility and advisability of the adoption of the metric system reported favorably as to its adoption, and that the report was adopted. The resolution adopted by the Institute endorses substantially the provisions of the bills now pending in the committee.

Very truly yours,

J. H. SOUTHARD,

Chairman Committee on Coinage, Weights and Measures, H. R.

Fifty-seventh Congress, first session, H. R. 123, Report No. 1701.

In the House of Representatives, December 2, 1901, Mr. Shafroth introduced the following bill, which was referred to the Committee on Coinage, Weights and Measures and ordered to be printed. April 21,

1902, reported with amendments, referred to the House Calendar, and ordered to be printed.

A BILL

To adopt the weights and measures of the metric system as the standard weights and measures in the United States.

"*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled*, That on and after the first day of January, nineteen hundred and four, all the departments of the Government of the United States, in the transaction of all business requiring the use of weight and measurement, except in completing the survey of public lands, shall employ and use only the weights and measures of the metric system; and on and after the first day of January, nineteen hundred and seven, the weights and measures of the metric system shall be the legal standard weights and measures of and in the United States."

COAL PRODUCTION OF THE UNITED STATES IN 1901.

The United States Geological Survey has prepared a preliminary report upon the production of coal in the United States in 1901, based upon the returns representing 97 per cent. of the entire output, which show that 292,240,758 short tons were mined during the year, valued at $348,813,831. As compared with 1900, when the output amounted to 269,881,827 short tons, worth $306,891,364, this represents an increase of 22,358,931 short tons, or 8 per cent. in quantity, and of $41,922,467 or 13·6 per cent. in value. The production of Pennsylvania anthracite showed a phenomenal increase—namely, from 51,221,353 long tons (equivalent to 57,367,915 short tons) in 1900 to 60,242,560 long tons, or 67,471,667 short tons, in 1901. This represented a gain of 17½ per cent., the largest percentage of gain made by the anthracite trade in 20 years. Part of this increase in 1901 was due to a decreased output of anthracite in 1900, as compared with 1899, as owing to the historic strike of 1900 the output that year was reduced by over 2,500,000 tons. The average price for the marketed anthracite coal—that is, the product shipped to market or sold to local trade, and exclusive of the colliery consumption, which amounted to about 10 per cent. of the total—was $2.05, the highest figure obtained since 1888.

The production of bituminous coal, lignite, cannel coal, etc., including a small amount of anthracite from Colorado and New Mexico, increased from 212,513,912 short tons in 1900 to 224,769,091 short tons in 1901, indicating a gain of 12,255,179 tons, or about 6 per cent. The value of this product amounted to $236,309,811, as compared with $221,133,513 in 1900, an increase of $15,176,298, or a little less than 7 per cent. The price of the bituminous product did not show any material advance in 1901, the average being about 0·8 cent higher than in 1900.

The preliminary report issued by the Inspector of Mines for Great Britain shows that the production of coal in the United Kingdom last yeat was 219,037,240 long tons, a decrease of 6,132,923 long tons from 1900. Reducing the

product of the United States to the same unit, it is found that it amounted to 260,929,248 long tons, which is 42,439,760 long tons, or nearly 20 per cent. more than that of Great Britain. The coal output of her colonies and dependencies (including India) aggregated in 1900 about 17,000,000 long tons, so that taking all the British Empire as one producer, it still falls short of the coal product of the United States last year by from 20,000,000 to 25,000,000 long tons. Our coal production last year was nearly 80 per cent. larger than Germany's, nearly seven times that of Austria-Hungary, and more than eight times that of France.

POPULAR ERRORS IN METEOROLOGY.

Professor Gannett, of the United States Geological Survey, has a paper in the Bulletin of the American Geographical Society which treats of popular errors in meteorology and geography, entitled "Certain Persistent Errors in Geography." A few of his points are summarized in what follows:

Forests and Rainfall: An example of the persistence of error is the idea that the presence or absence of forests has an influence on the amount of rainfall. Some keen observer long ago detected the fact that forested regions enjoyed a heavier rainfall than those not forested, and jumped to the conclusion that rainfall was produced by forests, and that the removal of forests diminished the rainfall. Looking over the earth he found many treeless desert regions and forthwith instanced them as frightful examples of men's wastefulness. Syria, Northern Africa, parts of Italy, are often quoted as illustrations of man's destruction of climate. In reply, man can certainly plead not guilty. The geography of this Mediterranean region, the configuration of land and water, and the direction of the prevailing winds, are such as to give it a light rainfall—forests or no forests. The situation is really this: Want of rain prevents the growth of trees; want of trees does not prevent rain. Forests and Floods: Another persistent error is the belief that floods in our rivers are more frequent than formerly because of the cutting down of forests in their drainage basins. It is probable that the clearing of land by cutting away forests and undergrowth does change the regimen of streams, increasing their flood-height and diminishing the flow at low stages. In other words, water probably runs off or evaporates more rapidly from bare ground than from ground covered with forests. But where the forests are cut away the ground is seldom left bare; it is cultivated or quickly becomes covered with bushes which hold the water quite as effectively as forests. The main fact is, however, that the floods in our rivers are no greater or more frequent now than in the past.

Climates and Ocean Currents: The well-known mild climate of the northwest coast of America is commonly attributed to the Japan Current. The Gulf Stream is supposed to have the same influence on the western coasts of Europe, etc. But can it be supposed that the Japan Current, however warm it may be when it leaves the tropics, retains any appreciable excess of heat after a journey of 6,000 miles in northern latitudes? As a matter of fact, no trace of this current reaches the shores of North America. In the North Atlantic the condition is much the same. The Gulf Stream disappears as a current long before the British Isles are reached.

Death Valley.

By Prof. Oscar C. S. Carter.

Judging from the many highly sensational stories and frequent references to Death Valley, there is evidently a popular interest in that dreaded locality, which is in part explicable by the name it bears. The stories published are, as a rule, of little value, and give no idea of the climate, topography, fauna and flora, of a more absolute and arid desert than the Sahara. Our great deserts of the southwest have been but little written about by geographers and travelers, and it is only recently that accurate official reports upon them have been made. Captain Clarence E. Dutton, in his report on the Grand Cañon, gave a description of the deserts of Northern Arizona. Captain Gaillard, of the Mexican Boundary Commission, has given us, in a popular magazine, probably the best article that has as yet been written on an American desert. He was well qualified to write, because he traversed the entire region from the Rio Grande to the Pacific, erecting monuments to mark the boundary between Mexico and the United States. Mr. W. J. McGee, Chief of the Bureau of American Ethnology, who recently made the journey through Southern Arizona and Mexico, to study the Seri Indians, who live on the Isle of Tiburon, in the Gulf of California, has given us a fine description of the desert in his report and in separate articles in the "Journal of Geography." A valuable article on the American Desert, by Robert T. Hill, has just appeared.

The above descriptions stand out like oases in a barren desert. These deserts of the Southwest, which take in the southern parts of California and Arizona, are called the Colorado Desert, from the river of that name which empties into the Gulf of California. They are hotter, dryer and more arid than the Sahara, as proved by the official records of the Boundary Commission. The early days of '49 saw much suffering and hardship endured by the overland trav-

elers across the desert to California, and one of the most pathetic stories of suffering ever told was narrated by the survivors of a Death Valley party. They followed the old Santa Fé trail through New Mexico and Arizona, the same that the Santa Fé Railroad now parallels. Those who traveled north from Mexico across the Colorado Desert to California shared even a worse fate, as their bleaching bones along the desert testify. In September, 1849, a party of 500 emigrants left Utah for the land of gold. Their household goods were carried in the typical prairie schooners drawn by oxen. They left full of hope and good cheer, but in time a dispute arose as to the route and the party divided; some went east to strike the trails between Santa Fé and the Pacific, but the main party forged ahead to cross the land of the mirage and thirst. When they reached the plateau country, the land of the mesa and cañon, their canvas-covered wagons were useless. The green of the upland and meadow, so familiar in their eastern home, was wanting here; instead long lines of plateau and mesas with steep precipitous slopes met their view at every turn. These glaring red table lands could not be crossed unless they knew the country, so they packed their belongings on the backs of the sturdy oxen and trudged wearily along across the burning arid wastes. One by one the oxen perished and starvation stared them in the face; some of the more vigorous pushed ahead and reached Death Valley, where they perished miserably. It is said that one poor fellow, left for dead, recovered sufficiently to crawl on his hands and knees more than two miles after his companions and then perished. The remnant of the expedition crossed the valley at a narrow part and lived for days on a jelly made from boiled ox-hide. Gaunt and emaciated they slowly climbed the mountains and the survivors were nursed back to health on a ranch in the fertile valley to the westward. The valley takes its name from this and other sad experiences.

It is known that men exposed to the sun's direct rays are occasionally made insane, and it is said that one man drove in on a load of borax to the borax works which are located in the valley, during a particularly torrid day, and expired

quickly, rigidly grasping in his stiffened fingers a water canteen. Birds in summer rarely try to fly across this alkaline expanse, and when they do, frequently drop dead in mid flight.

The animals, such as are found there in the summer, are mostly nocturnal, as might be inferred from the prevailing intense heat. Horned toads and other lizards and snakes constitute the fauna. Cooked meat spoils overnight, and raw meat dipped in brine is cured in a couple of hours. The bitter streams of alkaline waters which start from the surrounding mountains are eagerly sucked up and disappear before they flow far into the parched soils of the desert. And yet this region is well known; much better known than many other parts of this country. Occasionally an exploring expedition visits it, prospectors often wander into the valley in search of gold, and one lonely miner kept his cattle high up the mountains for nearly a year. Gen. Frederick Funston, before he had won his honors in the Philippines, was assistant to a Government botanical expedition, which in 1891 studied the flora of the desert and the surrounding mountains. The work in the valley was mostly done in the cool of winter, while the flora of the mountains was studied during the warm summer months.

Probably the first scientific expedition to the valley was made by the California Boundary Commission in 1861. Lieutenant Birnie, of Wheeler's Geological Survey Expedition, crossed it several times and made his camp in it for awhile. In 1891 the Botanical Expedition, headed by Frederick Vernon Coville, with Frederick Funston, assistant, explored this region. It was directed by Hart Merriam. This expedition was made with the co-operation of the U. S. Geological Survey and Signal Service, and was continued by Mr. John H. Clery of the Weather Bureau, under the direction of Chief Mark Harrington. It is to the reports of these gentlemen and independent observers that we are indebted for most of the information we have about the valley.

Location.—Death Valley lies in Southeastern California, not far from the boundary line of Nevada and about 50 miles due east of Owens Lake. It lies between mountains

in a section of country east of the Sierras. It is enclosed between the Funeral and Amargosa Ranges on the east, and the Pinto and Panamint Ranges on the west. These ranges are higher than the White Mountains of New Hampshire, and some of the peaks (as the Sentinel) are 9,856 feet high. They are not parts of the Sierra Nevada Range. The valley has a length of about 75 miles from northwest to southeast, and at the bottom is only 12 to 15 miles wide at the widest part. Opposite the borax works it is only 6 miles wide.

Below Sea Level.—The valley is one of the few areas in this country that are situated below the sea level. The barometric observations of Lieutenant Birnie show that a large part of the valley is 100 feet below sea level, and some parts much less. Williamson states that the valley is 175 feet below sea level. No doubt parts of the valley are much lower than these figures. There are some sinks along the Colorado River in Southern California which are also below sea level, but such localities are few in the United States.

Origin.—This valley was evidently occupied at one time by an inland lake of alkaline water, such as the Carson, Winnemucca and Humboldt Lakes of Nevada are to-day. As it slowly evaporated, the water became bitter from the excess of mineral matter until finally it disappeared altogether, leaving a deposit of salt, borax, etc., which even at this late day can be seen along the eastern border where the slight rainfall has not carried it away.

Borax Works.—Borax is an important salt in the arts. On the eastern side of Death Valley is located the Pacific Coast Borax Company. Some years ago they fenced in 30 acres, to which they gave the rather inappropriate name of Greenland Ranch. In order to raise what crops were needed for food, water was brought from the mountains in barrels and stored in two small reservoirs. With this supply they irrigated and raised several crops of alfalfa a year; by irrigating constantly, a few cottonwood and fig trees were grown. When the works were first started, 40 men were employed, who did not stay in the valley in summer. Their season began with September and ended in June.

Climate.—In winter the climate is not hard to bear. On the highest surrounding mountains it is quite cold and snow falls. In the valley it is comfortable. The fauna changes in the winter and jack-rabbits and cottontails visit the valley, as do migrating birds, such as ducks. This wide range of temperature in winter and summer is not unusual. At Yuma, in Southwestern Arizona, the temperature in winter falls to 27° Fahr., but in summer it is one of the hottest places in the United States. Even the neighboring Piutes cross the mountains and visit the Death Valley in winter. Early spring and late autumn are not hard to bear, although spring begins earlier there and scarcely any rain falls.

It is the hot stifling summer months that are unbearable. They sap the strength and vitality of the strongest. There was one employé of the Weather Bureau, Mr. John H. Clery, who stuck to it and stayed through the summer, under the most adverse and trying circumstances. His assistant was prostrated by the fearful heat and had to return to Keeler for treatment. Clery made his headquarters at the foot of Funeral Mountains, in a building owned by the borax works. He stayed there five months in the hottest part of the year. The soil near the station was a shifting white sand. No vegetation, except an occasional mesquite bush. The highest temperature reached was 122° in the shade. This temperature was reached for several days, and for three successive days in June, the hottest days he experienced, showed a maximum temperature of 120° F. In July, the hottest month, an average daily maximum of 116° was reached; although this maximum was exceeded in the desert of the Colorado and in parts of India, the average is higher than the averages of those places. We often hear higher temperatures quoted for deserts, but fail to consider they were not taken under official auspices, and that the instruments, not being properly shaded, were affected by reflected and radiated heat. Some of the temperatures quoted for deserts are absurd.

Death Valley, however, is not the hottest place in the United States. The highest temperature ever recorded by

official instruments in the United States was at Mammoth Hot Tank, California, in the Colorado Desert. There, in July, 1887, the temperature reached 128° F., in the shade, and on another occasion reached 126°. At Yuma, the highest official temperature was 118°. There they sleep out of doors, on roofs and porches, in summer, and work is done in the early morning hours before the sun comes up. Much higher figures have been quoted for Yuma, but they are not official. The writer found the Mohave Desert, in Southern California, in two different summers, and the Painted Desert, in Arizona, much too warm for comfort, and was reminded of the western stories of the army officer who had been stationed at Yuma for many years. Finally, he passed away, but returned from Hades to Yuma, for his overcoat.

Rains are not frequent in Death Valley, and curiously enough, the little rain that does fall generally comes down at night. For the entire period of five months, during which a record was kept and measurement was made with the rain-gage, not quite 1½ inches of rain fell. Many of the showers were so slight that they were merely traces, not enough to be measured by a gage. Agriculture cannot be carried on successfully in the United States without irrigation when the rainfall is less than 20 inches per year. When we consider the fact that in Pennsylvania we have an average rainfall of about 40 inches a year, and that in Oregon the rainfall reaches 100 inches per year, we realize what a slight rainfall the Valley has. No records of the rainfall in winter were kept, but if we compare it with the surrounding deserts we can get a pretty good idea. Such a comparison would lead us to assume that the rainfall is from 3 to 4 inches per year. There are other deserts in the United States which in summer show even less rainfall than the Valley. Nearly all the stations in the Desert of the Colorado, in California, show less rainfall than the Valley. Contrary to usual opinion the atmosphere is not sluggish and calms are not common. The prevailing wind is from the south and it is frequent, but in summer it is like the breath from a fiery furnace. Comparisons of temperature with oases in the Sahara and desert places in India show

that Death Valley is much hotter and dryer, and although the maximum may be exceeded in parts of the Colorado Desert and in India, yet the averages are higher.

The cause of the small rainfall is easily understood. The location and topography are unfavorable for even a moderate rainfall. A valley below sea level, surrounded by mountains in an arid region, would not receive much rain. The vapor-laden winds from the Pacific lose their moisture when they are cooled in ascending the slopes of the Coast Mountains of California and the Sierra Nevadas to the westward. The moisture is precipitated as snow and rain long before these winds reach this valley. Hence, when they do reach it, they are already deprived of most of their moisture. It is a well-known fact that cyclonic and anti-cyclonic areas move from west to east; in other words, our weather moves from the west towards the east. Notwithstanding this fact, were it possible for any winds from the east or southeast to reach this valley, they would be dry winds, because their moisture would have been removed by precipitation in crossing the Rockies, and afterward the high plateau country of New Mexico, Northern Arizona and Utah.

CENTRAL HIGH SCHOOL, June 1, 1902.

SOME RECENT ELECTRIC FURNACE PRODUCTS.

Although the pulverization of metals in the electric furnace forms the subject of several patents issued in this country and abroad, but little is known of the practical operation of the methods or of the nature or use of the several products obtained.

The general method is simple in the extreme. A metal is heated either by the arc or by the passage of a heavy current through a column of reduced cross section, and is thereby brought to the temperature of volatilization. Vapors so produced are, in most cases, directly combustible in air, burning freely to oxide, or may be subjected to various reagents with corresponding variety in the products; or, finally, the metal may be collected directly in comminuted form in an inert atmosphere. The applications of the method embrace the manufacture of a whole series of pigments, abrasives, refined metals, and miscellaneous reagents.

In 1896, the Société Civile d'Etudes du Syndicat de l'Acier Gérard, of Paris, patented abroad a method designed primarily for the production of steel from iron by a modified Bessemer process, the principal feature of which was the comminution of the metal before subjecting it to a graduated blast

of air, the effect being, as in the converter, the oxidation of silicon, sulphur, phosphorus and carbon, and the conversion of the pig metal into steel. As one method of pulverization, the employment of the arc was suggested, the fused metal falling in a stream between the ciruit terminals and collecting after passing through an air blast in the hearth of the furnace.

Later, a modified construction was adopted wherein a metal formed a short circuit between water-cooled terminals, and the air blast was projected against its surface at the point of maximum temperature; the vapor was thereby oxidixed, and carried over to a collecting chamber forming a part of the furnace.

The substitution of other metals for pig iron suggested at once several modifications of this process, to wit: the comminution of lead for use in accumulators; the production of litharge by the concurrent oxidation of the lead; the production of zinc as a sublimate, or, in the presence of an air blast, of zinc white; the production of rich mattes of copper, or the pulverization of this metal as a preliminary to the extraction of the contained values; the production of powders of bronze, tin and aluminum, which enter in many ways into industrial processes; and finally the comminution of chrome—or tungsten—steels, to serve as abrasives.

An analogous procedure for the manufacture of white lead has been patented in this country to Messrs. Bailey, Cox & Hey. In this process the arc is struck from a tabular electrode to the surface of a mass of molten lead. Commingled vapors of water, carbon dioxide and acetic acid, introduced through the hollow electrode, are presumed to react with the vaporized lead to form commercial white lead; the function of the acetic acid in this process is not clear and its use is probably merely a relic of various prior methods operating at temperatures at which the acid is stable.

Messrs. Bredig and Haber have noted in the *Berichte* a curious phenomenon, which occurs when the arc is struck beneath the surface of the electrolyte, either acid or alkaline, to a lead wire cathode, or when high cathode current densities are used under these conditions; the metal is disintegrated, appearing as a cloud in the solution, and white lead may, it is said, be produced by merely injecting air and carbon dioxide. The method is, of course, not a commercial one.

Recently M. Barry, of Paris, patented a furnace for the commercial production of stannic acid. The molten metal is included as a resistance in the circuit, and the vapors as they escape from an orifice in the furnace cover are ignited by an air blast, and the dioxide collected. The Tin Electro-Smelting Company, Limited, of Paris, which controls this patent, is also marketing a series of pulverized metals, presumably made in an analogous manner. These are an impalpable powder of tin, known in France as argentine, and capable of giving, by simple rubbing, a burnished foil-like surface to paper; several grades of pulverized aluminium, the finest constituting the base of a new high explosive, and the coarser grades adapted for use in thermite reactions, as, for instance, the reduction of oxide of chromium, etc.; and pulverized lead, employed for the manufacture of minium, of white lead, and particularly for the production of sodium nitrite.—Clinton Paul Townsend in *Electrical World*.

Mining and Metallurgical Section.

Read at the Stated Meeting, held Wednesday, December 11, 1901.

Upon the Structure of Metals and Binary Alloys.

By William Campbell, B.Sc. (Durham), F.G.S.

(*Concluded from p. 142.*)

In Group III no eutectic in the true sense of the word exists. The examples of this group are:

Bismuth and antimony.
Silver and gold.

When an alloy of gold and silver commences to solidify, dendrites comparatively rich in gold begin to form. The mother-liquor is enriched in silver. As the temperature falls, the dendrites continue to grow larger and larger, but as each coating of metal is less rich in gold than the one previous, and as diffusion (in the case of slow cooling) produces a uniformity of composition or an equilibrium in the dendrites, these latter become richer and richer in silver, till at the point where the whole alloy becomes solid they have the composition of the original alloy. Of course, if equilibrium is not established we get mixed crystals, or in other words the dendrites are richer in gold at the center than at the outside.

A fourth group might be added—where a compound is formed and we get two divisions:

(1) An excess of the first metal or the compound crystallizing out in the eutectic of this metal and the compound.

(2) An isomorphous mixture of the compound and the second metal.

To this group would belong antimony and silver and perhaps tin and silver. Thus this group is really a combination of Groups I and III.

Charpy groups together alloys with abnormal curves of fusibility. Amongst them are:

Copper and tin.	Antimony and tin.
Copper and zinc.	Zinc and silver.

TIN AND ZINC.

The cooling curve of the series (*Fig. 33*) is composed of two inclined branches meeting at 8 per cent. zinc. The

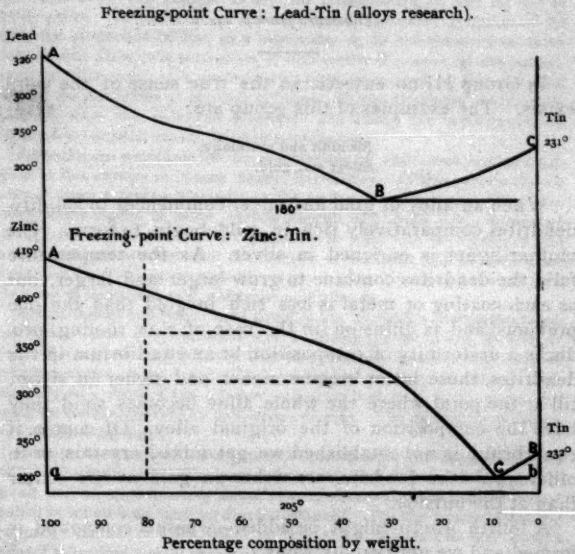

FIG. 33.

horizontal branch corresponding to the freezing of the eutectic occurs at 205° C., and extends from almost pure tin to almost pure zinc; in other words, as soon as a very small quantity of one metal is added to the other a eutectic is formed, for the concentration of the solid solutions formed is very dilute.

Then between tin and the eutectic alloy containing 8 per cent. zinc we find grains, and then dendrites of tin set in an increasing groundmass of eutectic. The solidification of the tin is marked by the break *B C* in *Fig. 33*, whilst that of the eutectic is denoted by the break *b C*. Below *b C* the alloys are solid; between *B C b* we have a mixture of solid grains or dendrites of tin in a liquid whose composition will depend upon the temperature.

Between zinc and the eutectic alloy we find grains, dendrites, and then long, attenuated, lath-like bodies of zinc surrounded by increasing amounts of eutectic. The solidification of the zinc is marked by the break *A C*, whilst that of the eutectic is denoted by *a C*. Then, as before, below *a C* all the alloys are solid. When an alloy cools down from the liquid state, it remains entirely liquid till its temperature reaches that of the curve *A C*. For example, take the alloy containing 80 per cent. zinc. At 390° C. the first grains of zinc begin to form and the mother-liquor is enriched with regard to tin. As the temperature falls, the zinc grains grow and the mother-liquor becomes richer and richer in tin. Thus at 350° C. it will contain about 47 per cent. of tin; at 300° C. about 72 per cent.; whilst at just above 205° C. it contains about 92 per cent. At 205° C., that is, the temperature *a C b*, the mother-liquor solidifies and the temperature remains constant till the whole mass is solid; then the temperature falls normally in the solid mass. *Fig. 19* shows an alloy containing 20 per cent. zinc, 80 per cent. tin. The long, lath-like grains of zinc are seen with their distinct tendency towards parallel growth. *Fig. 17* would well illustrate the appearance of an alloy containing between 60 and 70 per cent. Zn.

LEAD AND TIN.

The cooling curve for these two metals, taken from the Report of the Alloys Research Committee (London), is shown in *Fig. 33*. It consists of two inclined branches meeting at the eutectic point, 68 per cent. tin, 32 per cent. lead. The horizontal branch corresponding to the solidification of the eutectic occurs at 180° C. and probably extends

further than shown, for it would appear in this case also that the concentration of the solid solutions formed was very minute. The meaning of this curve is the same as that of the tin-zinc series. Alloys containing more than 68 per cent. Sn remain liquid until their temperature reaches *C B*. At that point pure tin or almost pure tin crystallizes out of the mother-liquor and continues to crystallize out till the mother-liquor reaches the composition of 68 per cent. Sn, which it does at 180° C. At that point it solidifies as a eutectic of alternate laminæ more or less curved of lead and tin, without any fall in temperature. When solidification is complete the temperature falls normally. Alloys containing less than 68 per cent. Sn remain liquid till they reach the temperature of branch *A B*, when lead commences to crystallize out, enriching the mother-liquor in tin. Crystallization continues until the mother-liquor has a composition of 68 per cent. Sn at 180° C., when it solidifies as before.

The surface structures of these alloys when cast, and also when slowly cooled, give a good indication of their internal structure. *Fig. 20* shows the surface structure of the alloy 15 per cent. Pb; 85 per cent. Sn when cast. The large dendrites of tin, differently orientated, are seen standing out above the surface. The eutectic, in cooling and solidifying, has shrunk and sunk beneath the level of the dendrites, which thus stand out in relief. *Fig. 21* shows the surface of an alloy from the other end of the series. It contains Sn, 26 per cent.; Pb, 74 per cent. It is taken from a small ingot. In this case the dendrites are those of lead, which stand out above the level of the eutectic. The difference in size of the dendrites of tin and lead is great.

Fig. 22 shows the effect of copper upon common solder. Five per cent. of copper was added to the solder (2 Pb : 1 Sn) giving an alloy, Pb 63 per cent., Sn 31 per cent., Cu 5 per cent., in which three constituents can be seen. The long, rough crystals of a compound of copper and tin have crystallized out first of all; then the excess of lead has solidified as grains and dendrites, and last of all, the eutectic has solidified.

LEAD AND ANTIMONY.

The curve of fusibility is composed of two branches which cut at a sharp angle at the eutectic point, 13 per cent. Sb at 228° C. according to Roland-Gosselin,* and 247° C. according to Stead.† *Fig. 34* shows the curve.

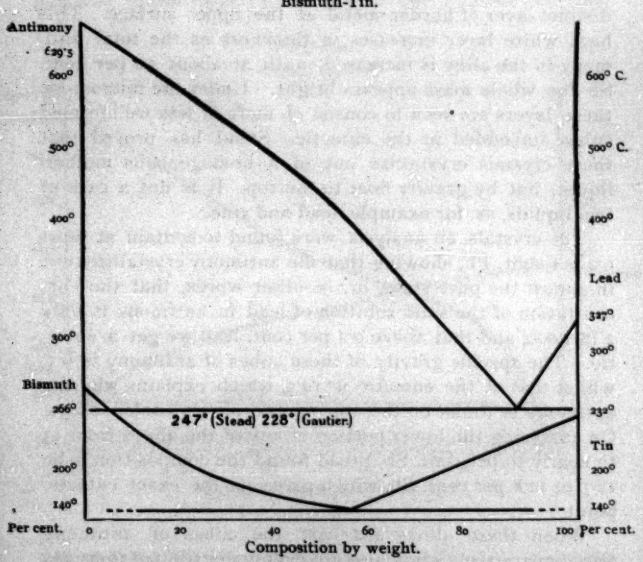

FIG. 34.

Alloys containing 0 to 13 per cent. Sb are extremely difficult to polish and etch properly. They are seen to consist of grains and then dendrites of lead in a matrix composed of alternate bright and dark laminæ, Sb and Pb. *Fig. 23* shows

*Gautier: *Bull. de la Soc. d'Encourage.*, 1896, Tome I, 5e Série.
†*Journal Society Chem. Industry*, March and June, 1897.

the 10 per cent. Sb alloy, and the large skeleton crystals of lead are seen to have solidified in the eutectic. This eutectic corresponds to the formula Pb_4Sb, but this does not mean that a compound exists, but that the eutectic happens to have a percentage composition which corresponds to a formula. An exactly similar case is that of Levol's alloy.

Above 13 per cent. Sb the slowly cooled alloys show a distinct layer of harder metal at the upper surface. This hard white layer increases in thickness as the total antimony in the alloy is increased, until at about 50 per cent. Sb the whole mass appears bright. Under the microscope these layers are seen to consist of more or less well-formed cubes imbedded in the eutectic. Stead has proved that these crystals crystallize out of a homogeneous mother-liquor, but by gravity float to the top. It is not a case of two liquids, as, for example, lead and zinc.

The crystals, on analysis, were found to contain at most 0·2 per cent. Pb, showing that the antimony crystallizes out in almost the pure state, or, in other words, that the concentration of the solid solution of lead in antimony is only 2 in 1,000, and that above 0·2 per cent. lead we get a eutectic. The specific gravity of these cubes of antimony is 6·5, whilst that of the eutectic is 10·5, which explains why the antimony is found on the top of the slowly cooled alloys. On analyzing the lower portion of any of the alloys from 13 to nearly 50 per cent. Sb, Stead found the composition to be 12·7 to 12·8 per cent. Sb, which gives us the exact eutectic point.

When these alloys are cast the cubes of antimony are comparatively small and are evenly distributed throughout the mass, thus allowing the alloys with the lower percentages of antimony to be used as bearing metals. *Fig. 24* shows the surface of an ingot containing 75 per cent. Sb, 25 per cent. Pb. The cubic growth of crystals of antimony resembles closely that of pure bismuth. As in the other illustrations of surface structures, the eutectic on cooling has shrunk and the antimony crystals stand out in relief. *Fig. 30* is very similar to the appearance of the bright layer

of antimony cubes in slowly cooled alloys containing from 15 to 30 per cent. of antimony.

TIN AND BISMUTH.

The curve consists of two branches meeting at 143° C.* (Rudberg). The eutectic contains about 46 per cent. bismuth, 54 per cent. tin, and under high powers has a peculiar granular appearance. From tin to the eutectic we find

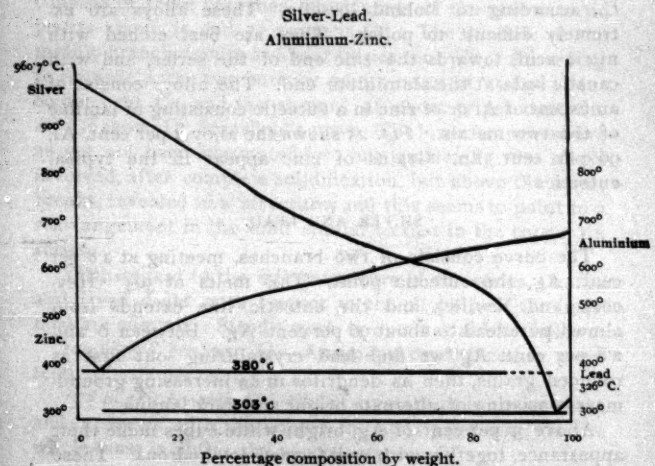

FIG. 35.

grains and then dendrites of tin crystallizing out in the eutectic. The alloys are similar in appearance to *Fig. 23.*

Above 46 per cent. Bi, irregular white crystals of bismuth make their appearance. In this case, however, their density is greater than that of the eutectic, and consequently they form and sink to the bottom when the alloy is slowly cooled.

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* *Poggendorf's Annalen de Physik und Chemie*, xviii, 240. *Annales de Chimie et Physique*[2], xlviii, 353.

When cast they appear regularly throughout the mass. The cooling curve, *Fig. 34*, is based upon Dr. Gautier's figures in the "Fusibility of Metallic Alloys."

ZINC AND ALUMINIUM.

The two branches which compose the curve meet at about 5 per cent. Al. The eutectic melts at 380° C., some 39° below zinc, according to Heycock and Neville,* or 389° C., according to Roland-Gosselin. These alloys are extremely difficult to polish. They are best etched with nitric acid, towards the zinc end of the series, and with caustic soda at the aluminium end. The alloys consist of an excess of Al or of zinc in a eutectic consisting of laminæ of the two metals. *Fig. 25* shows the alloy 4 per cent. Al, 96 per cent. Zn. Grains of zinc appear in the typical eutectic.

SILVER AND LEAD.

The curve consists of two branches, meeting at 2·8 per cent. Ag, the eutectic point. This melts at 303° (Heycock and Neville), and the eutectic line extends from almost pure lead to about 96 per cent. Ag. Between 0 and 2·8 per cent. Ag we find lead crystallizing out first as rounded grains, then as dendrites in an increasing groundmass consisting of alternate bright and dark laminæ.

Above 3 per cent. of Ag, bright white cubes make their appearance, together with well-formed octahedrons. These are silver, but contain some lead in solid solution. As the silver contents are increased, these octahedrons increase, tending to crystallize out along definite directions, and forming in this way large skeleton crystals of silver. *Fig. 26* shows this mode of growth in an alloy containing 10 per cent. Ag, 90 per cent. Pb. The skeleton crystals become more compact, the octahedrons forming them become less perfect, and there is a great amount of interference as the silver is increased. At 50 per cent. the silver forms a dense

* *Journal Chem. Soc.*, 1897, p. 383.

mesh throughout the alloy. This increases in thickness and the eutectic diminishes till at 96 per cent. Ag the whole mass appears to be made up of silver grains and dendrites. These alloys are best etched by prolonged action of acetic acid.

ANTIMONY AND COPPER.

The curve of fusibility, as determined by Le Chatelier, consists of three branches, which cross at the two eutectic points about 25 and 71 per cent. Cu. The summit of the middle branch occurs at about 60 per cent. Cu. According to Stansfield, the two eutectic points occur at 25 and about 69 per cent. Cu, and the summit at about 57 per cent. Cu. *Fig. 36* shows Dr. Stansfield's curve. The lower branches have as yet not been accounted for; but quenching the alloys involved, after complete solidification, but above the lower breaks, revealed new structures and this seems to point to a rearrangement in the solid similar to that in the copper-tin series.

With regard to the microstructure of the series, Charpy and Stead differ with respect to the alloys near the intermediate summit. Stead's work is summarized as follows:

100 to 75·8 per cent. Sb.—Antimony crystallizes in a eutectic of 24·2 per cent. Cu.

75·8 to 48·5 per cent. Sb.—$SbCu_2$ crystallizes in the eutectic, and increases with the copper, till at 51·5 per cent. Cu the whole mass is $SbCu_2$, the purple compound.

48·5 to 38·5 per cent. Sb.—The purple compound $SbCu_2$ crystallizes imperfectly in what appears to be a second definite compound, $SbCu_3$, which is white; the purple compound decreases and finally disappears when the Sb reaches 38·5 per cent., the whole mass being composed of a compound, white in fracture and when polished, but purple on etching with HCl.

Sb 38·5 to 31 per cent. Sb.—The structures of the alloys between 38·5 and 36 per cent. Sb are similar in appearance; thin veins envelop the grains, and from these veins needle-like processes penetrate into the grains for a very short distance. As the antimony is decreased below 36 to 31 per

cent., microliths of some compound appear in the center of the grains, and the veins enveloping the latter increase in thickness and in their copper contents. When 31 per cent. Sb is present, the microliths are present in increased quantity, and at this point it would appear that we have the second eutectic with a very complicated structure.

31 to 0 per cent. Sb.—As the copper is increased above 69 per cent. it at first falls out of the eutectic in detached iso-

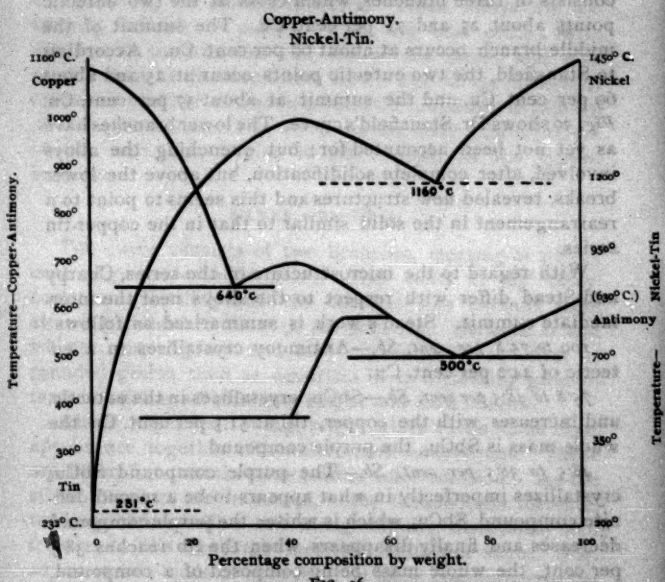

FIG. 36.

lated globulites. They are not pure copper, but contain Sb and arrange themselves in definite lines and angles. As the copper is increased, they form dendritic crystals. The microliths are absent and have probably been absorbed by the yellow-colored dendrites at the moment of solidification. The color of the dendrites passes from yellow to red as the

Sb is further reduced, and finally the last 0·1 or 0·2 per cent. are left behind at the borders of, but not separated from, the grains of copper, where it probably exists as antimonide of copper in solid solution. (Stead: *Journal Soc. Chem. Industry*, Dec. 31, 1898.)

Charpy's conclusions are as follows:

In the case of alloys containing less than 25 per cent. copper, pure crystals of antimony are separated when solidification begins, increasing gradually in size as the temperature decreases; the portion remaining liquid, therefore, gradually becomes richer in copper until the composition of the eutectic alloy is reached; it then solidifies at a constant temperature, through a simultaneous crystallization of Sb and $SbCu_2$. In the case of alloys containing from 25 per cent. to 60 per cent. Cu, a similar phenomenon occurs, only it is the definite compound $SbCu_2$ which separates from the molten mass as soon as the freezing point is reached. When from 60 per cent. to 70 per cent. of copper is reached, the same compound is separated, but is in this case surrounded by a second eutectic alloy made up of copper and the compound $SbCu_2$. Finally, when more than 70 per cent. of copper is present, a portion of the latter is first deposited when solidification sets in, until the portion remaining liquid has reached the composition of the second eutectic alloy (*Metallographist*, Vol. I, p. 100).

TIN AND NICKEL.

According to Charpy, the microstructure and the curve of fusibility seem to show that they have a constitution very similar to that of the copper-antimony alloys. The eutectic points occur at 2 per cent. and 70 per cent. Ni, whilst the summit of the intermediate curve occurs at about 43 per cent. Ni.

In *Fig. 36* the curve according to Gautier is shown.

ALUMINIUM AND ANTIMONY.

Gautier points out that the curve of fusibility of these alloys is remarkable, since nearly all its points correspond

to temperatures higher than those of the fusion of the two metals. He says that the curve indicates the formation of a compound SbAl, whose fusion-point is slightly lower than that of copper. Dr. Mathews' curve is shown in *Fig. 12* of his paper.

On a microscopic examination these alloys fall into two groups:

(1) 0 to 81·5 per cent. antimony, in which increasing amounts of the compound SbAl crystallize out, first as short rod-like crystals, then as more or less irregular bars and plates with much parallel growth. The groundmass is aluminium or aluminium containing some SbAl in solid solution. The groundmass disappears between 75 and 80 per cent. Sb and the alloy appears homogeneous.

(2) 81·5 to 100 per cent. antimony, in which we pass from the compound through a series of alloys composed of crystals of SbAl in an increasing groundmass till we reach pure antimony. The groundmass could not be resolved into two components, and probably consists of antimony containing some of the compound in solid solution.

The series is remarkable in many ways; for when the antimony reaches about 60 per cent. the alloys soon become rotten and rapidly disintegrate into a fine black powder. This is due to oxidation, according to Gautier; for if the alloy be weighed before and after disintegration it will be found to have gained in weight. If the fresh alloy be sealed up in vacuo, no change takes place. Again, when the antimony in the alloy is between 50 and 80 per cent. a great expansion takes place during solidification and part of the liquid residue is squeezed out and solidifies as a button on top of the alloy. That it takes place during the solidification of the crystals of SbAl is shown by the fact that the button contains a large percentage of the compound as well formed crystals. Lastly, it is seen that the curve consists of a rise from the aluminium end to the alloy containing 33 per cent. Sb. This is a summit, and the curve falls to 37 per cent. Sb, after which it rises again to 81·5 per cent. Sb. The reason for this has not yet been explained, for under the microscope the alloys between 33 and 40 per cent. Sb pre-

sent the same characteristics. A similar thing occurs in the alloys of tin and aluminium.

SILVER AND TIN.

The curve, like that of the silver-lead series, consists of two branches, the one curved, meeting at the eutectic point 3·5 per cent. Ag. The eutectic melts at 222° C. and extends from almost pure tin to 65 per cent. Ag, where it disappears.

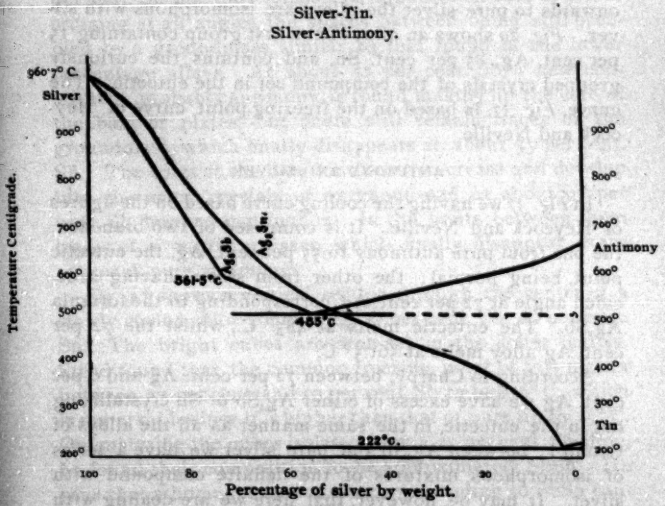

FIG. 37.

According to Charpy, we have a compound Ag_2Sn at 65 per cent. Ag, and thus the series can be divided into—

(1) Alloys which are isomorphous mixtures of Ag and Ag_2Sn—between 100 and 65 per cent. Ag.

(2) Alloys of the compound Ag_2Sn and Sn, which are quite normal.

Between 0 and 3·5 per cent. Ag we find the excess of tin crystallizing out as grains in the eutectic. Above 3·5 per cent. Ag we find long, slender needles, probably of the com-

pound Ag_3Sn crystallizing out. The number and size of these hard, bright crystals increase with the total silver in the alloy. They assume curious tree-like shapes, finally becoming united and forming dendrites. At about 50 per cent. they occur as rounded grains in close contact. The eutectic diminishes, and at 65 per cent. Ag we find the alloy homogeneous. This alloy may either be a definite compound or it may be a solid solution of tin in silver. From this point onwards to pure silver the alloys are isomorphous with silver. *Fig. 29* shows an alloy of the first group containing 15 per cent. Ag, 85 per cent. Sn, and contains the curiously grouped crystals of the compound set in the eutectic. The curve, *Fig. 37*, is based on the freezing-point curve of Heycock and Neville.

ANTIMONY AND SILVER.

In *Fig. 37* we having the cooling curve based on the figures of Heycock and Neville. It is composed of two branches: the one from pure antimony to 55 per cent. Ag, the eutectic point, being normal; the other from silver, having a decided angle at 72 per cent. Ag, corresponding to the formula Ag_3Sb. The eutectic melts at 485° C., whilst the 72 per cent. Ag alloy melts at 561·5° C.

According to Charpy, between 72 per cent. Ag and 0 per cent. Ag we have excess of either Ag_3Sb or Sb crystallizing out in the eutectic, in the same manner as all the alloys of Group I; between Ag_3Sb and pure silver we have a series of isomorphous mixtures of the definite compound with silver. It may be, however, that here we are dealing with a case similar to the antimony end of SbSn series, and that we have dendrites of silver crystallizing out in the compound Ag_3Sb. This point will be settled when a complete cooling curve has been taken of this end of the series.

TIN AND ANTIMONY.

Between 0 and 7·5 per cent. of antimony the alloys crystallize out in the same forms as pure tin; in other words, the tin will retain some 7·5 per cent. of Sb in solid solution, probably in the form of the compound SbSn. When the

antimony is increased above 7·5 per cent., some very hard, bright cubes are found at the surface of the alloy when slowly cooled, but when cast the cubes are found scattered throughout the alloy. The bright layer of cubes increases in thickness with the antimony in the alloy, till at about 30 per cent. Sb it reaches the base of the alloy, and the groundmass is seen occupying the interstitial spaces. At about 40 per cent. the form of the cubes begins to change, and at 45 per cent. Sb the alloy consists of squat, thick bars or plates crossing at all angles, the spaces between being still occupied by a groundmass similar to that found in the lower percentage alloys. At about 52 per cent. Sb, a new constituent, probably antimony, is found making up the core of the bars or plates, but there still remain traces of the groundmass, which finally disappears at about 55 per cent. Sb. The cores of the bars continue to increase and develop into the usual crystals of antimony and, at about 95 per cent. Sb, become continuous. In the joints between them traces of a matrix are seen, which finally disappear as we approach pure antimony.

Fig. 30 shows a vertical section through the center of a slowly cooled alloy containing 20 per cent. Sb, 80 per cent. Sn. The bright cubes are seen set in the softer matrix. Stead found that the common freezing point of this matrix between 7·5 per cent. and 50 per cent. Sb to be 256° C., which is remarkable since it is higher than that of pure tin by 25° C. On analyzing the cubes isolated from a 25 per cent. Sb alloy, he found their composition to be approximately SbSn. He says that a homogeneous mass corresponding to SbSn cannot be obtained, for on melting the metals in that proportion the resulting alloy consisted of the peculiar plates and the dark matrix; that the crystals up to 30 per cent. Sb are SbSn, but in the neighborhood of 40 per cent. Sb the forms begin to change and the contents of antimony increase. This is contrary to Behrens,* who isolated from the 10 per cent. alloy cubes with the formula $SbSn_2$, and from the 64 per cent. Sb alloy a residue of the formula SbSn.

**Metallographist*, Vol. III, page 11.

According to Stead, the specific gravity of the cubes is 6·96, which is lighter than that of the groundmass, and thus they float to the top of the slowly cooled alloys, just as the antimony in the lead-antimony alloys. *Fig. 31* shows the surface structure of the cast 25 per cent. Sb alloy, in which the cubes are quite distinct. In *Fig. 32* we have the 70 per cent. Sb alloy, showing the crystals of antimony set in a matrix, which is probably SbSn, containing much antimony in solid solution. Stead puts forward the alternate view that Sb and SbSn may form isomorphous compounds with each other, and when the antimony reaches a certain point it crystallizes out in a separate state.

The alloys of tin and phosphorus and of tin and arsenic probably belong to the same group as tin and antimony.

TIN AND PHOSPHORUS. TIN AND ARSENIC.*

When phosphorus is added to tin, a hard constituent, consisting of brilliant white plates, similar to graphite, is formed. Stead has studied the series from 0·04 per cent. to 5 per cent. phosphorus. The structure of these alloys can be developed by polishing alone, for the phosphide formed stands out in relief from the soft matrix of tin between. On etching with dilute acid this groundmass of tin (probably containing some phosphorus in solid solution, for its melting point is 4° C. above that of pure tin), turns black, and the hard white crystals of phosphide stand out in strong contrast. When analyzed the bright white plates proved to have the composition Sn_3P_2. When the alloy is slowly cooled the phosphide invariably commences to grow at the outer portion of the alloy and travels in straight lines toward the center. The plates have a decidedly hexagonal form. *Fig. 28* shows an alloy containing 2 per cent. phosphorus; it has been cast, and so the phosphide appears as comparatively small thin plates throughout the groundmass.

When arsenic is added to tin, thick rough plates are formed, having the composition Sn_4As_3. The groundmass consists of tin, probably containing some arsenic in solid

* Stead: *Journal Society Chemical Industry*, March, 1897.

solution, because, as in the case of phosphor-tin, the melting point has been raised some 4° C. Stead was able to introduce as much as 43 per cent. As into tin. *Fig. 27* shows a slowly cooled alloy, in which the thick rough plates of arsenide run in all directions, with a tendency towards parallel growth. The alloy contains 20 per cent. As.

COPPER AND TIN.

The microstructure of the copper-tin alloys has been studied by Behrens, Charpy, Stead, Heycock and Neville. The earlier explanations were based on Le Chatelier's curve of fusibility, which consists of three branches forming by their intersections two points corresponding to alloys with 3 and 72 per cent. of copper. These two points correspond to the two eutectic alloys of the series. The existence of the compound $SnCu_3$ (61·7 per cent. Cu) has been proved, for at this point we find discontinuities in the variations of many properties, such as the electromotive force of dissolution (Laurie); the electric conductivity (Mathiessen); the specific gravity (Riche). Hence it was thought that the series consisted of two simple sets of alloys, viz.: the alloys of copper and $SnCu_3$ and the alloys of $SnCu_3$ and tin, and was similar in structural variation to the alloys of copper and antimony.

This view of the constitution of this series of alloys does not explain the complete freezing-point curve published in the fourth report of the Alloys Research Committee, Institution of Mechanical Engineers, shown in *Fig. 38*. It was not until recently that an explanation of the branches *b*, *d* and *e* was offered.

0 to 1 per cent. Copper.—When 1 per cent. of copper is present the first eutectic alloy is obtained; that is, the one with the lowest freezing point. Between pure tin on the one hand and this alloy containing 1 per cent. Cu on the other, tin is found crystallizing, first in grains, then in dendrites in the eutectic. The cooling curves of all the intermediate alloys show two breaks.

1 to 8 per cent. Copper.—When the percentage of copper is increased above that of the eutectic alloy, thin, bright, hol-

low crystals are seen. In section they are horseshoe-shaped, and at first occur isolated; then they tend to form groups which appear in section as three- and six-rayed stars. Their composition varies also, increasing in copper from 34 to 44 per cent.

8 to 40 per cent. Copper.—A third constituent is seen when the copper exceeds 8 per cent. We have the eutectic or groundmass enclosing the bright porphyritic crystals characteristic of the 1 to 8 per cent. alloys, but these bright crystals are seen in places to have grown on and around a different kind of crystal. It is not a case of one crystal varying in composition from the center to the faces, for a sharp line of junction can be seen between the two constituents. On oxidation this new constituent becomes very dark, and is easily distinguished from the other two constituents of the alloy. As the percentage of copper is increased, the more easily oxidized crystals increase in number and size; whereas the bright crystals begin to decrease together with the eutectic. It would, therefore, appear that in alloys containing more than 8 per cent. of copper, the first constituent to crystallize out is the central, easily oxidized crystals. This causes the first rest in the cooling curve *d e*. Then the bright crystals solidify, causing the second halt on the horizontal branch *e' e*. Lastly the eutectic solidifies and the third halt is reached on branch *f' f*. As branch *e' e* is horizontal, it would seem that the bright crystals have a definite composition when above 8 per cent. Cu is present in the alloy, but when branch *e' e* joins the outer curve at *e* and falls to *f*, these crystals no longer have a definite composition, but their percentage of copper falls with their temperature of solidification from Sn_2Cu_3 to SnCu.

The upper curve in *Fig. 38* shows the relation between the percentage of copper in the alloy to the percentage of copper in the crystals which have been isolated. A break occurs at 8 per cent. copper, at the introduction of the third constituent to the alloys. These results agree very closely with those of Stead.*

* *Journal Society of Chemical Industry*, June, 1897.

As the copper approaches 40 per cent., the central plate-like crystals are grouped together in parallel bunches, until at 40 per cent. Cu they are very thick and cover more than half the field. In the eutectic between them the small, bright, hollow crystals are seen.

41 to 61·7 per cent. Copper.—The difference between the alloy containing 40 per cent. and that containing 41 per

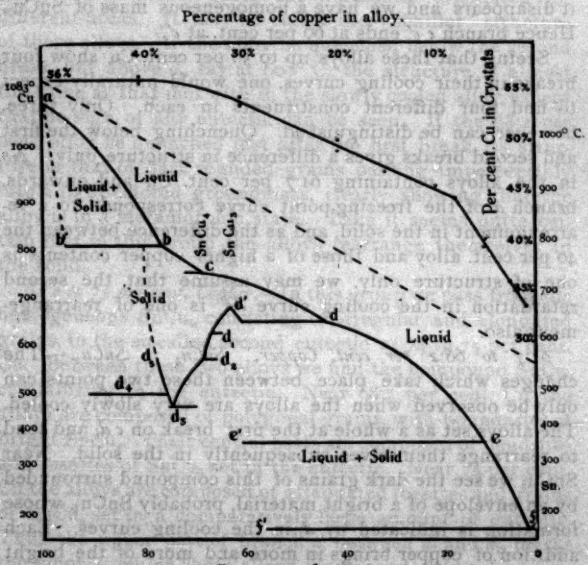

FIG. 38.

cent. Cu is very marked. The crystals in the latter are small and lath-shaped, arranged more or less in groups and are separated from each other by eutectic. They are composite as before, but the white constituent surrounds the dark as an envelope of uniform thickness, not as a rough incrustation. No single prismatic crystals of the white constituent have been seen in the eutectic. With each

addition of copper the groups of crystals become more and more compact and the amount of eutectic diminishes until at 56 per cent. Cu it disappears altogether.* Therefore branch *f f'* of cooling curve ends at 56 per cent.

The bright constituent of the crystals grows smaller and smaller; at 56 per cent. Cu it takes the place of the eutectic and forms the groundmass, whilst at about 61 per cent. Cu it disappears and we have a homogeneous mass of $SnCu_3$. Hence branch *e e'* ends at 60 per cent. at *e'*.

Seeing that these alloys up to 56 per cent. Cu show four breaks in their cooling curves, one would naturally expect to find four different constituents in each. Only three, however, can be distinguished. Quenching below the first and second breaks gives a difference in structure only. As in the alloys containing 61·7 per cent. Cu and onwards, branch *d* of the freezing-point curve corresponds to a rearrangement in the solid, and as the difference between the 40 per cent. alloy and those of a higher copper contents is one of structure only, we may assume that the second retardation in the cooling curve *dd'* is one of rearrangement also.

61·7 to 68·2 per cent. Copper. Sn_2Cu_3 to $SnCu_4$.—The changes which take place between these two points can only be observed when the alloys are very slowly cooled. The alloys set as a whole at the first break on *c d*, and tend to rearrange themselves subsequently in the solid. Near $SnCu_3$ we see the dark grains of this compound surrounded by an envelope of a bright material, probably $SnCu_4$, whose formation is indicated by d_1 in the cooling curves. Each addition of copper brings in more and more of the bright constituent. Above 65 per cent. Cu we find, in places, a structure like that of a eutectic which accounts for the horizontal branch d_2 of the curve. At 68·2 per cent. Cu we have a homogeneous alloy, very brittle, taking a beautiful polish, and this very probably is a definite compound, $SnCu_4$. When the alloys of this group are quenched at definite temperatures, very many curious and beautiful

* Stead: *J. S. C. I.*, June, 1897.

structures are met with. For example, if the 66 per cent. Cu alloy be quenched below the first break, say at 720° C., then a clear cell-like structure is seen. If it is quenched between the first and second break, say at 650° C., then the structure consists of a network of parallel straight lines, alternately light and dark. Each large area has two or more sets of lines, which are differently orientated for different areas. It may be called the "Schiller" structure of these alloys. If the alloy be quenched below the second break, but above d_2, say at 600° C., the structure is almost the same as that met with in the slowly cooled alloy, except that no sign of any eutectic can be seen. If the 68·2 per cent. alloy be quenched just after the first break, its structure is that of dark rounded grains passing imperceptibly into a light-colored groundmass, clearly showing that the alloy is in a metamorphic state. Thus it seems quite certain that in this group the alloys rearrange themselves in the solid.

68·2 to 75 per cent. Copper.—In this group we pass from the homogeneous $SnCu_4$, consisting of irregular and elongated grains, to the so-called second eutectic at 74 to 75 per cent. Cu. Between these two alloys we find the compound $SnCu_4$ crystallizing in the eutectic. Near 68·2 per cent. Cu the alloys are composed of polygonal grains, with boundaries of bright $SnCu_4$. Their central parts are composed of dendrites and rosettes of $SnCu_4$ set in the eutectic. Near 74 per cent. Cu the alloys are composed of attenuated rosettes and grains of $SnCu_4$ set in a comparatively large amount of eutectic. Thus the upper part of branch d, between d_2 and d_3, marks the point at which these alloys rearranged themselves into grains isomorphous with $SnCu_4$, whilst the horizontal branch d_3 marks the formation of the eutectic, both changes having taken place in the solid. At c there occurs a small horizontal branch, the meaning of which is not quite certain. A microsection of an alloy quenched between this and the outer curve shows dark rounded grains set in a light groundmass. Heycock and Neville say that the outer curve $b\ c$ indicates the formation of skeletons rich in copper; but when the alloys are quenched below the horizontal branch c, then

we have uniform solid solutions. It is to be noted that on the surfaces of alloys containing 70 per cent. or more copper, a network of dendrites or skeleton crystals resembling those on the surface of a pure metal is to be seen. It was soon noticed that the internal structure of the alloys from 70 to 75 per cent. Cu showed no trace of these dendrites, and so the surfaces of several were rubbed down, polished and etched so as to lay bare their internal structure. In each case it was the same as that of the center of the alloy, which shows that these dendrites have split up and rearranged themselves after solidification, and all that remains of them is this surface structure.

75 to 100 per cent. Copper.—Above 75 per cent. Cu two new constituents make their appearance and the alloy assumes a yellow tint and begins to lose its brittleness. In section we find yellow grains surrounded by a bright white border, set in the second eutectic, in which small white grains also occur. Now this eutectic at 76 per cent. Cu is much larger in character than the 74 per cent. alloy, and this may account for the fact that the eutectic break rises some 30° C. as it passes from 74 to 75 per cent. Cu.

As the total copper is increased the yellow grains increase, forming dendrites and skeleton crystals, the white borders and grains merge together, and the eutectic decreases till at about 90 per cent. Cu it disappears. The yellow grains of copper become darker and darker (contain less and less tin in solid solution) till they reach copper color. The light borders diminish and disappear about 95 per cent., leaving copper dendrites alone. These dendrites vary in composition from center to outside, and so the center etches a darker color. These dendrites darken with increase of copper till about 100 per cent. is reached, when we have the characteristic structure and color of pure copper.

Quenching these alloys at different temperatures proves that copper grains and dendrites begin to crystallize out as soon as an alloy has reached the temperature of the outer curve *a b*; that these continue to grow till the temperature falls to *b' b*, when the whole mass becomes solid; at this

point we have crystals of copper in a homogeneous groundmass. Above the curve *a b* the alloy is liquid, below *b' b* the alloy is solid, whilst between *a b* and *b' b* we have a mixture of solid and liquid. The composition of the copper dendrites crystallizing out of any particular alloy would be given by the composition line *a b'*.

Below *b' b* the groundmass consists of a solid solution much richer in tin than the grains of copper in it. It is probable that these grains of copper continue to grow in the solid until at about 500° C. the groundmass has arrived at the composition 75 per cent. Cu, when it splits up into a eutectic composed of laminæ of $SnCu_4$ and Cu, containing a considerable amount of Sn in solid solution. This change in the solid is marked by branch d_4.

The meaning of branch d_5 is obscure. It may indicate the formation of the bright white grains seen in the 76 and 77 per cent. alloys.

In their recent papers before the Royal Society of London and elsewhere, Heycock and Neville* have clearly proved that the great changes which take place when a bronze reaches the temperature of the curve *d' . . . . d*$_4$ are entirely in the solid. They go further than this by determining the various substances or phases which exist in the various alloys, either chilled or slowly cooled. Their modification of the cooling-curve diagram by the addition of a curve indicating the position of the *end* of solidification of each alloy and their explanation of this new diagram, go far in clearing up many of the numerous difficulties met with in the alloys of copper and tin.

ALUMINUM AS A SUBSTITUTE FOR COPPER.

The possible substitution of aluminum for copper in electrical work is a question which has been discussed from time to time in the press; frequently, we regret to say, by writers who apparently know very little about the facts. It has also been referred to by electricians, some of whom have been able to speak from actual experience. From the expert testimony it appears that

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* *Proceedings Royal Society of London*, Vol. 68. *British Association*, Glasgow Meeting, 1901, Chem. Section.

aluminum can be and has been used for conducting purposes in power plants and for the transmission of power from such plants. The most notable employments of the metal for the former purpose have been in some of the recent installations at Niagara and in some California plants; for the latter at Snoqualmie Falls in Washington, and the Blue Lakes power plant in California. Notes of these uses of the metal have appeared in our columns from time to time; and its use at Blue Lakes was fully treated by Dr. F. A. C. Perrine in a paper read before the Institute of Electrical Engineers.

The testimony of experts is that aluminum has given good results where it has been used; and that its lesser conductivity, as compared with copper, and its lower tensile strength, requiring the use of bars and wires of larger section, are so balanced by the low specific gravity of the metal that in the matter of cost aluminum at its present prices is about equal to copper at 16 to 17 cents a pound—that is, at present prices. For transmission wires there still seems to be some doubt whether, in a northern climate, aluminum wires will stand the stresses of snow, ice and high winds as well as copper. In a milder climate this consideration might be disregarded.

It may be assumed, therefore, that it would be possible to substitute aluminum for copper in electrical work to a considerable extent—provided the metal can be had in sufficient quantities for the purpose. That is, after all, the most important question. For all immediate purposes the question seems to be answered by the fact that in 1900 the total production of aluminum in the world was 5,570 metric tons, of which the United States furnished 2,053 tons; while that of copper was 492,625 metric tons, of which 272,536 tons were supplied by this country—that is, the total output of aluminum last year was only 1·1 per cent. of that of copper. Until these figures are greatly changed, the competition of aluminum is not likely to affect the copper market.

The price of aluminum at present is—as stated above—about on a par with that of copper, allowance being made for the respective weights. The aluminum quotations, however, have not been regulated by those of copper, but have been based, as we understand, upon the cost of production. They have shown little change during the past year. There is no competition tending to lower them; but on the other hand it is to the interest of the producers to keep them as low as possible in order to dispose of their output.

The main point to be considered, therefore, is to what extent the production can be increased. There is a general indefinite idea prevalent that as alumina is so abundant and so universal in its occurrence, it ought to be possible to extend the extraction of its metallic base indefinitely. That this is not the case is shown sufficiently—without going into details—by the fact that present production is so small, although the best metallurgical skill has been for years concentrated on the problem of separating the metal.

We do not mean to say that cheaper and more expeditious processes of furnishing aluminum may not be discovered hereafter. That is a problem which may be worked out by some investigator to the great benefit of the world—and himself. It has not been done yet, and considering present conditions, as we must, we are unable to see any opening for the substitution of aluminum for copper—or for any other metal—on a commercially important scale.—*Eng. and Mining Jour.*

Mining and Metallurgical Section.

[*Joint meeting of the Section and the American Institute of Mining Engineers, held Wednesday, May 14, 1902, at the Manufacturers' Club, Philadelphia.*]

The Beaumont Oil Field, with Notes on Other Oil Fields of the Texas Region.

By Robert T. Hill, Washington, D. C.

(*Continued from p. 94.*)

OIL-FIELDS OF THE TEXAS REGION.*

While the phenomena of the Beaumont field have attracted great attention, many are not aware of the fact that in the State of Texas there are several other oil-fields (productive or prospective) entirely distinct from the Beaumont field, and from one another, in geological and geographical conditions. One of these has been productive for many years, while the others may some day give profitable returns.

One of these fields is already a large producer of a high-grade illuminating oil, supplying nearly 1,000,000 barrels per year of oil as good as that of the Washington County (Pa.) field. There are also many localities where bitumen occurs as asphaltum.

The typical oil and asphaltum horizons of Texas are as follows:

The Beaumont.
Nacogdoches.
Corsicana-San Antonio (Uvalde asphalt).
The St. Jo (asphalt).
The Brownwood-Henrietta.
The Trans-Pecos.
The Buckhorn (asphalt).

* See also "Bulletin U. S. Geological Survey," by George I. Adams, Washington, 1901.

Of these, one asphalt-field is found in the Ordovician rocks; two oil-fields (the Brownwood-Henrietta and the Trans-Pecos) in the older (Carboniferous) rocks of the Coastal Plain; and the others in the Cretaceous and Tertiary. I shall briefly describe each of these fields in ascending stratigraphic order, which also corresponds to their relative importance.

In the Southern Indian Territory there are, in Ordovician and Carboniferous formations, many asphalt springs and bituminous rocks which show the presence of a great amount of bituminous material. These asphaltic deposits have been recently described in detail by the United States Geological Survey in a paper entitled "The Asphalt and Bituminous Rock Deposits of the United States," by George H. Eldridge.*

THE PECOS OIL-FIELD.

In Reeves, Pecos and El Paso Counties, Texas, and in Eddy, Otero and Chaves Counties, of southeastern New Mexico, there is a prospective field in which many "seeps" have been found, and oil in small quantities has been struck in wells. This region lies immediately west of the Pecos River, and extends north of the Southern Pacific Railroad, far into Southern New Mexico, and adjacent to the eastern slope of the Guadaloupe Mountain uplift.

The geological series seems to have, primarily, a great thickness of indurated Carboniferous limestone at the base; then a series of sands and bituminous shales; then another vast thickness of Upper Carboniferous and Permian limestones; then shales and clays of Permian or Triassic Age; then the basement-sands and limestones of the Comanche Cretaceous; the whole being largely obscured toward the Pecos Valley by large quantities of wash and desert debris. The geological structure consists of a long monoclinal uplift dipping, from the western crest of the Guadaloupe-Sacramento Range and the Comanche Range, eastward

* See "Twenty-second Annual Report of the Director of the U. S. Geological Survey," 1900-1901, Part I.

toward the Pecos River. This monocline is waved by numerous secondary anticlines and synclines, and steep faults to the west. By reason of the ease with which the many low secondary anticlines and synclines can be made out, this structure is apparently more propitious for the location and extraction of oil than that of any other Texas field.

Most of this area lies upon the eastern slope of the monoclinal mountains of the Comanche and Guadaloupe-Sacramento Range. A few oil-indications have been found farther west, in the Salt Basin flat.

Within the area mentioned, oil, asphaltum and sulphur have been encountered at numerous places in wells or springs, and upon the surface; and while the region has not yet been minutely studied, there is every indication that by scientific study and exploration it can be developed into an oil-field. Unfortunately, the only drawback, up to date, is the fact that the oil thus far encountered is of a very inferior quality, containing, as shown by Professor Phillips,* a residue of 45 per cent. of asphaltic material, and only about 25 per cent. of all grades of illuminants.

THE HENRIETTA-BROWNWOOD FIELD.

In this field, coincident with the Carboniferous outcrops in Northern Central Texas and the Southern Indian Territory, numerous finds of oil have been made in small quantities, notably at Henrietta, Clay County, and in Brown and Coleman Counties.

These Carboniferous formations are of great thickness (over 7,000 feet in Texas), and apparently contain many oil-bearing horizons. They also furnish some of the maltha springs of the Chickasaw Nation in the Indian Territory, and the oil and gas of the Northern Indian Territory and Kansas. No oil in commercial quantities has as yet been found in this field; but the quality of that hitherto found has been good. Exploitation is proceeding rapidly.

* "Bulletins Nos. 1 and 2 of the Mineral Survey of Texas," Austin, Tex., 1901–1902.

BITUMINOUS HORIZONS IN THE BASE OF THE CRETACEOUS.

The basement-beds of the Comanche series of Texas and the Southern Indian Territory are bituminous in several places, notably between Emmet and Caddo, I. T.; at Matubby Springs, about 5 miles northwest of Caddo; at Oakland, 16 miles southwest of Emmet; and at Marietta.* At these localities the basement-sand of the Cretaceous is impregnated horizontally. Crossing Red River to the southward, rich bituminous impregnations are similarly found in the basement-sands near St. Jo, Montague County. Some 200 miles further south, in Burnet County, asphalt is again found in the vicinity of the town of Burnet, impregnating small breccia at the base of the Cretaceous.

There are several minor beds of shale and clay in the Cretaceous, which have furnished traces of petroleum and asphalt. A mile or two west of Austin, a little petroleum was found in the Del Rio clays. Traces of petroleum have frequently been found in the Eagle Ford shales, notably at Watter's Station, north of Austin, and in the northwest in Grayson County, on Red River.

THE CORSICANA OIL-FIELD.

Since 1891, illuminating oil has been produced in the vicinity of Corsicana, where the Standard Oil Company has had a refinery. In 1900, the production of this district was 829,560 barrels. The oil is of fine quality, analogous to that of Washington County (Pa.) field, and has a paraffine base. The wells are not gushers, but are pumped from depths averaging about 1,100 feet.

Unlike the oil of the Beaumont field, that of Corsicana is distinctly a sheet-oil; that is, occurs in a definite geological stratum, namely, a horizon in the bituminous sandy clay shales of the Navarro beds, of the upper portion of the Gulf series of the Cretaceous. The geological position is closely near that of the Florence and Boulder oil-fields of Colorado.

An interesting feature of the Corsicana field is the fact that the Upper Cretaceous strata from which the oils are derived contain at least two distinct oil-bearing horizons:

*See paper by Eldridge, previously cited.

the uppermost has an asphaltum base, while the lower is of a paraffine nature. The upper bed is encountered at Powell, about 20 miles east of Corsicana; and I estimate that it is from 500 to 1,000 feet above the lower, which supplies the Corsicana wells.

These strata extend, with very slight variation, completely across Texas, from near Boston on Red River to near Eagle Pass on the Rio Grande, in a curved line 750 miles long. An oil-asphaltum has been found in them at several places, notably, a trace in the well at Bremond; a trace in Eastern Travis County; near Elgin, near Lytton in Caldwell County; a few miles east of San Antonio; and on the Sabinal in Medina County. The asphaltum-beds of Uvalde and Kinney Counties are derived from practically the same strata. It is the writer's opinion that when the continuity of this bituminous formation across the State has been fully appreciated and exploited in a scientific manner, many productive spots, similar to the Corsicana basis, may be found

THE NACOGDOCHES OIL-FIELD.

A number of years ago, oil was struck at shallow depths in wells in Southern Nacogdoches County, about 100 miles west of north from Beaumont. According to the studies of various geologists, the horizon of this oil-field is near the top of the Claiborne Eocene of the Tertiary.

A fine-grained quartz-sand, saturated with oil, which on the outcrop is a semi-asphalt, is apparently the source of the oil. It lies immediately below a green horizon, the outcrop of which is easily traceable by its blood-red soil, a product of the oxidation of glauconite.

Since the discovery of oil at Beaumont, renewed interest has been awakened in Nacogdoches, and several wells are being drilled.

At many other localities throughout the outcrop of the Eocene Tertiary of Texas, traces of oil have been found. Much interest is now shown in the vicinity of Sutherland Springs, Wilson County. A good oil is also reported 14 miles south of Campbellton, near the junction of Atascosa, McMullen and Live Oak Counties.

THE BEAUMONT OIL-FIELD.

This name the writer prefers to use for the oil-producing district within the area of the Coast Prairie of the Texas, Louisiana and Mexican Region.

Discovery.—Before the first white man came, it was known that oil existed in small quantities in Western Louisiana and Texas, within 100 miles, more or less, of the present site of Beaumont. It was a matter of rumor for many years that oil floated upon the sea just west of Port Sabine. Petroleum springs existed at several places, notably, Lake Charles, La. It had also been encountered in the well-borings in Western Louisiana, East of Beaumont. As early as 1862, unprofitable attempts at drilling had been made at Sour Lake. Even at Beaumont, similar attempts failed. Until 1901, no man had obtained the oil in commercial quantities.

The finding of oil at Beaumont was not an accident, but, like all other great discoveries, the dramatic culmination of long and extensive research and many experiments, each of which was an important factor in the final result. Capt. A. F. Lucas, to whom the glory of the crowning achievement is fairly due, has been, since 1892, carefully studying the geology of the Coastal Plain of Western Louisiana and Eastern Texas, with the view of developing its salt, sulphur and petroleum. With the aid of every recorded observation which he could obtain, supplemented by his own experience and reasoning, he concluded that the structure and stratigraphy of Beaumont gave the best prospect of oil. Previous failures at this place were, in his judgment, due to mechanical difficulties, which could be overcome—an opinion which he fully confirmed by his work.

Captain Lucas, a native of Austria, and graduate of the Polytechnic School of Gratz and of the Imperial Austrian Naval School, had been for some ten years actively engaged in this country as a mining engineer, especially in the development and operation of the salt mines of Louisiana.*

In connection with this work he found, in one or two

* See his paper on "Rock-Salt in Louisiana," *Trans.* A.I.M.E., xxix, 462.

places, indications of oil, and also of sulphur (of the existence of which, in that region, the famous Calcasieu deposit is a proof). Conceiving the plan of a systematic exploration for oil, he finally chose Beaumont, Tex., as the scene of operations. His first well, begun in 1899, was 575 feet deep in March, 1900, and showed a trace of oil at the bottom, when the casing broke, and the well had to be abandoned. Not daunted, he commenced in October, 1900, another well beside the old one. The public will never realize the obstacles and difficulties which had to be overcome. One of Captain Lucas's greatest technical achievements was the putting of a drill hole through 1,100 feet of clay and quicksand. The methods and contrivances used by him made possible the other wells which have followed. This second well, which "came in" January 19, 1901, was the famous "Lucas Gusher."

Economic Conditions of the Beaumont Oil-Field.—The Beaumont oil, when first discovered, was found to be of a different quality from that of any other field, and many doubts arose as to its value and uses. Having a heavy base of asphaltum, and being thoroughly impregnated with sulphur, it was supposed to have no value as an illuminant, and many believed that the excess of sulphur would so corrode boilers that it could not be used as a fuel. This sulphur was so apparent that on occasions, as on March 4, 1902, it filled the atmosphere, leaving a coating of sulphur on many of the houses in Beaumont, some 3 miles from the oil-field.

The chemical analysis of the oil is as follows:

COMPOSITION OF BEAUMONT OIL. FROM CHEMICAL ANALYSES BY PROF. F. C. THIELE.

I.

	Per Cent.
Kerosene	36·00
Light lubricating oil	21·05
Medium lubricating oil	21·05
Heavy lubricating oil	10·52
Asphalt	6·34
Loss and gases, including sulphur	5·04
	100·00

Color of crude oil: brown, opaque.
Sp. Grav., 0·9206, equal 22° B. at 62·57° F.

II.

Naphtha	6·45
Kerosene	35·00
Lubricating oil	43·90
Residue and gases	14·65
	100·00

Test of obtained kerosene:

Color	Prime white.
Sp. Gr.	0·872 equal 30° B. at 65·5° F.
Flash-point	120° F.
Fire-test	150° F.

It was soon realized that, if fit for no other uses, this was an excellent fuel. After a year of experiment, it is now generally conceded that the oil has many excellent qualities, and that, after refining for the kerosenes, the remainder is as good a fuel and gas-making material as can be desired. Upon the basis of elaborate refinery, chemical and fuel-tests, made on large quantities, the following facts may be stated as established: (1) The Beaumont oil has a low flash-point of 120° F., which renders it an unsafe, or at least undesirable, cargo in tank-ships; (2) refined by first distillation, it produces 30 per cent. of export illuminating-oil, leaving a residuum of good fuel-oil, which can be transported with perfect safety; (3) the sulphur can be extracted if necessary, but when left in the oil has no injurious effect whatever upon the boilers, while it adds to the fuel value; (4) as a fuel, three barrels of this oil can be delivered by rail in any city in Texas at a price of $2.70, the price of bituminous coal being $5, and that of anthracite coal $10 per ton. The oil may be laid down in New York, Philadelphia or Boston at 75 cents a barrel.

The flash-point of the crude oil is too low for marine insurance, but this defect can be obviated by a profitable preliminary refining, whereby the naphtha and kerosene are extracted, and the flash-point is raised to a standard for safe shipment.

Immediately after the discovery at Spindle Top every acre within 50 miles was leased, and wells were started everywhere. Since, then, it took from three to six months to put down one of these costly wells, some time was

required to show by experiment that all the oil in the immediate vicinity of Beaumont was confined to Spindle Top Hill, within an area of less than 300 acres.*

This was at first seriously discouraging. Many thought that if the oil was confined to this one small locality it would soon be exhausted, and the business would be at an end. Prudent operators at Spindle Top did not feel justified in making longtime contracts; and railways and factories, with the risk of an exhausted supply before them, naturally hesitated to make the expensive changes required for the use of this fuel.

The "coming in" of Jennings, Sour Lake and Saratoga removed the fear of inadequate supply; and no one now apprehends an early cessation of production, even if Spindle Top should soon be exhausted, which has not been proved probable.

When the Beaumont well was discovered, the writer, aware that similar conditions existed over a wide area, ventured the following prophecy:

"It is entirely within the limit of probability that oil will be found at many places throughout the Coastal Prairie, especially in its southern extension toward the Rio Grande and in the northeastern State of Mexico at Tamaulipas. The outcrop of the Tertiary formations in Southwest Texas, in Wilson, Atascosa, McMullen, Duval and other counties, is naturally rich in oil, and the practical oil-men are risking their money in experimenting in this region. As the oil-bearing Tertiary strata extend east of the Mississippi into Mississippi and Alabama, it is not beyond possibility that oil may be found in these States."

The following data, showing the results of one year's exploitation, sufficiently confirm this declaration, which was received at that time with incredulity:

At Jennings, La., 150 miles east of Beaumont, a good flow of oil has been encountered. This well is 1,830 feet deep, and is described as a mild sort of "gusher." In the

* The exact extent of the productive ground of Spindle Top Hill has not yet been determined, because several of the largest corporations own large tracts on one side of the hill, where the limits have not been exploited. It is known that this field certainly exceeds 200 acres; and most of the oil-men think it will reach 300 or 325 acres. It is still occasionally widened by new wells.

morning it spouts about 35 feet, and at other times just high enough to make a good flow. Although this oil is accompanied by a great deal of sand which chokes up the well, it demonstrates the broad geological fact which I asserted. Practical oil-men have such faith in the locality that a dozen or more well-rigs are at work. The sand-problem is a mechanical difficulty which all are confident will be overcome.

Proceeding west from Jennings toward Beaumont, oil has been found in varying quantities at Lake Charles, near Crowley, and in one or two other places.

At Sour Lake, 25 miles northwest of Beaumont, oil has been known to exist since 1862; and a dozen years ago many pumping-wells were operated, and a small refinery was established. The field was abandoned; but after the Beaumont discovery numerous well-rigs were set up to penetrate to greater depths. From seven to eleven different oil-strata were passed through, and in August, 1901, a well, similar to that at Jennings, was obtained by the Guffey people. Its product has not been reported.

On March 7, 1902, another great oil-strike was made at Sour Lake, at a depth of 685 feet, by the Atlantic & Pacific Company. It is said that the oil shot 150 feet into the air, and was of better quality than that at Beaumont.

Twelve miles north of Sour Lake, at the village of Saratoga, where the oil outcrops at the surface as maltha, it is said that a good oil-well has been obtained, flowing several thousand barrels per day.

Rockland, north of Saratoga, is the next place where oil-deposits are found, and experimental boring has been going on here for some time. The sand-rock near the surface is completely impregnated with oil.

Between Sour Lake and Houston, 50 miles farther west, many experiments are in progress, but no success has been reported. In the city of Houston, I was informed by Major Cave, of the Houston & Texas Central Railway, that a small flow of oil had come from his well for many years.

Fifty miles south of Houston, near the mouth of the Brazos River, in Brazoria County, there is a field which,

V. 19

according to Captain Lucas and the geological evidence which we possess, gives excellent indications for oil. There were no less than fourteen expensive well-rigs set up in this and Brazoria County, four of which were upon the remarkable hill known as Damon's Mound, one or two at Big Hill, and one at Keyser's Mound.

The wells on Damon's Mound encountered small flows of oil at depths of from 400 to 600 feet, exactly as at Beaumont; but so far they have been unsuccessful in securing a commercial flow.

At Keyser's Mound, in the same county, about 6 miles north of Damon's, and near the Brazos River, a flow of oil was struck at about 400 feet; but unfortunately the drillers were unable to cut off a tremendous flow of artesian water which was encountered just above it; and, as a result, the well produces to-day a remarkable emulsion of oil and water.

The well at Velasco (Bryan Heights) struck, at about 600 feet, a flow of gas so violent that its roar could be heard for miles. As a gas-well, this was as remarkable a phenomenon as were the Spindle Top oil-"gushers." The flow of gas could never be controlled; the well had to be abandoned, and a new hole, started beside the old one, is now giving every indication of securing oil.

Proceeding southward throughout the vast desert of the Lower Rio Grande, small quantities of oil have been encountered at several places, while still farther southward, at the end of our Coastal Plain, some miles from Beaumont, authentic reports have recently been received that flowing wells have been developed at Tampico, Mexico. Even as far south as the State of Tobasco, two flowing wells are reported. These results of a single year, although still fragmentary, are sufficient to reinforce our belief that in the future years the Beaumont field will furnish other profitable localities of commercial oil beside Spindle Top.

A Year's Development.—On January 10, 1902, one year from the date of the discovery of oil, there were 136 wells on Spindle Top. Operations for the first three months of the second year show a great increase; the number of "gushers"

has grown from 136 to 214, and more wells are drilling at present than at any previous time.

Three pipe-lines have been finished, two to Port Arthur (19 miles) and one to Sabine (24 miles). Pipe-lines to Beaumont to New Orleans and Beaumont to Galveston, Houston, and other Texas points, are contemplated.

On March 1st, the tank-storage exceeded 5,000,000 barrels. Among the tanks of 37,000 barrels capacity and over were twenty-two at El Vista, twenty-eight at Gladys, and thirty-three at Port Arthur.

The demand for tank-cars has constantly increased. In February, 1902, 500 cars were added, making a total at that time of 1,500. The Southern Pacific Railway has since purchased 250 tank-cars of 12,850 gallons capacity each, and many of the cars have already arrived at the loading racks. Many companies now have ample shipping facilities. In addition to the regular tank-car lines, there are between 800 and 1,000 tank-cars owned by local oil-companies. A huge tank-car factory is being erected at Beaumont to supply the demand.

Tank-steamers also have been in great demand. Many ships have cleared from Port Arthur; but the supply nowhere approximates the demand. The Guffey Company is constructing five steamers, one of which, to carry 60,000 barrels, is the largest ever made in America, and will equal any in the world.

The Guffey Company already has two refineries completed at Port Arthur, and another approaching completion. Work on five other refineries is progressing rapidly. Guffey Refinery No. 3, at Port Arthur, will have a capacity of 2,500 barrels per day. This company will ship no crude oil, but will bring the flash-point up from 120° to 145° and 150°, by taking out naphtha and kerosene before shipment.

Within a year from its discovery, Beaumont oil is burning in Germany, England, Cuba, Mexico, New York and Philadelphia. By its energy steamers are being propelled across the ocean, trains are hastening across the continent, electricity generated and artificial ice frozen in New York, ores ground and stamped in Mexico, Portland cement manu-

factured in Havana and Texas, and gas enriched in Philadelphia; and this, too, while half the world is either unaware or incredulous of the value of this fuel.

A strong demand for the oil comes from the manufacturers of illuminating gas. In March, this demand from New York and Philadelphia was great enough to justify a daily steamer from Port Arthur to those cities. The oil is also being sent to Atlanta and other cities for this purpose.

Many of the great railway lines of Texas have changed or prepared to change from coal to oil as fuel for their locomotives. The oil is also being used in hundreds of small factories in Texas, such as breweries, brickyards, etc. Even the farmers are using it as a fuel sufficiently inexpensive to permit of pumping for irrigation.

The production of the Beaumont oil-field during its first year was limited for the lack of means of distribution. It is estimated, however, that 5,500,000 barrels were actually drawn from the great reservoir—one-half of which was stored in tanks and the remainder consumed, shipped or wasted.

The shipments for 1901 were 1,750,000 barrels; for the first three months of 1902 they exceeded that total, those for March alone being more than 800,000 barrels. The field will probably ship 20,000,000 barrels in 1902.

It is estimated that the development of this field has cost $7,000,000, of which about $1,250,000 has been paid for labor. The tubing and well-drill rigs have cost, approximately, another million. Pipe-lines, lumber for derricks, and tanks for storing the oil, have consumed the remainder.

The average cost of sinking a well at Spindle Top is $7,249. The 215 wells that are "in," together with the adjacent "dusters," have cost fully $2,000,000. Probably $50,000,000 more have been expended for purchases of land, transportation facilities, and other legitimate purposes. The capitalization of the 200 companies in the field is placed at $200,000,000.

Before Captain Lucas's well came in, land could be purchased anywhere in the Coast Prairie country for less than $4 an acre. Millions of acres have since changed hands at

fabulous prices, while every foot has been leased for favorable considerations. Thousands of acres of this land 150 miles from Beaumont have sold for as much as $1,000 per acre. Land within the proved field has sold for nearly $1,000,000 an acre; $900,000 having recently been paid for one acre. No sales were made for less than $200,000 per acre. Spindle Top to-day may be justly assessed at a valuation of $500,000 an acre, or $100,000,000. Two years ago it could have been bought for less than $10 an acre.

The 214 wells upon the field are owned by about 100 companies. It is estimated that 120 of the wells are located upon 15 of the 200 acres of productive territory. These wells are in the hands of nearly as many individual companies, mostly small organizations without means for operation or facilities for outlet and transportation. The remainder of the territory is within the hands of four or five legitimate operators, who not only possess wells, but tank-cars, pipelines, refineries, etc., for handling and marketing the oil.

[*To be concluded.*]

Notes and Comments.

CANYONS AND SIERRAS OF THE GREAT SOUTHWEST.

On Friday evening, February 14th, under the auspices of the Franklin Institute and Y. M. C. A. at Association Hall, Prof. Robert T. Hill, of the U. S. Geological Survey, lectured on the above subject. Mr. Hill was formerly State Geologist of Texas and professor in the University of that State. He is well qualified to speak on this subject, as his expedition was the first to explore the canyons of the Rio Grande in Texas, some of which have vertical walls over 1,700 feet in height and contain some of the wildest and most rugged scenery in the United States. Before describing his journey, Mr. Hill gave a general description of the cordilleran, or elevated region of western United States. It is divided into three parts: First, the high forested mountainous region; second, the high plateau country of Utah, Arizona and New Mexico, and, third, the great deserts of the Southwest. The great problem of the deserts is irrigation, and while enormous areas favorably located as regards watersheds could be successfully irrigated, still, contrary to popular opinion, the greater parts of these deserts could never be irrigated either by artesian wells or impounding streams, or building dams across canyons and ravines to store water. The rainfall of the deserts is less than 15 inches per year, and on the Colorado Desert, in Southern California, the rainfall is less

than 3 inches per year. When we consider the fact that it takes from 25 to 100 acres of watershed to collect enough water to irrigate one acre of land, the hopelessness of the task in a greater part of the arid tract is readily understood. Then, again, 60 per cent. of stored water in the arid region is lost by evaporation. The air is so dry that it takes up water like a sponge, and loss by evaporation is very rapid. It is a common practice to cover ponds near windmills on certain ranches with boards to lessen evaporation. Parts of the desert of the Colorado, in Southern California, are hotter and dryer than any deserts in the world. And yet, notwithstanding this fact, 150,000 acres at Salton are now being irrigated by flooding the section with the waters of the Colorado, which empties into the Gulf of California. This tract will now produce everything that can be grown in a sub-tropical country—figs, oranges, limes and apricots grow luxuriantly.

When this river overflowed its banks a few years ago, and ran across the desert, it was soon carpeted with green grass, and the cattlemen soon had thousands of cattle feeding on this new-made grazing-ground. The desert is not always barren. When the slight rain falls, wild flowers and the resurrection plant spring up, and young cacti and mesquite push their heads above ground, and for a time, at least, the desert blooms like a garden, soon to be blasted by the burning sun and shriveled by the dry air. Southern California, the land of sunshine and flowers, is merely a reclaimed desert. When the Spanish traveled north from Mexico and settled in the valleys, under the guidance of the padres, they began to irrigate and reclaim what is now called by some the garden-spot of the United States. Some years ago the U. S. Geological Survey, under Powell, surveyed and mapped out areas of deserts in the States of the Southwest which are available for irrigation, and the subject is again being agitated by Congress at the present Session. Mr. Hill showed a beautiful series of rare desert-views in various parts of Texas, New Mexico and Arizona, and spoke of the fauna and flora of these arid wastes. In the plateau country, mesas, or flat table-topped plateaus, are characteristic. And in New Mexico volcanic necks and stumps stand out bold and prominent on the desert. The desert is scarred in places with enormous lava-flows, whose jagged cindery masses extend for miles. Some of these flows are so fresh as to prove that it was but a few years since the flows poured across the desert. The typical bad man and treacherous Indian are to a certain extent things of the past, and one can now stand on the mountains near Bisbing, Ariz., and see the stacks of the smelters of three of the largest copper mines in the world, and yet it is but 15 years ago that Geronimo and his band of cruel Apaches held full sway in this region. The railroads of these mines now parallel the Southern Pacific Railroad for 75 miles or more through one of the finest copper regions of the world.

The deserts of Texas support thousands of cattle; they are good grazing lands when not available for irrigation. The State leases the lands to the cattlemen for 6 cents per acre and the revenue goes to the school fund of Texas. After this general description of the deserts Mr. Hill gave a detailed account of his perilous journey through the wilderness of canyons of the Rio Grande. He was sent by the United States Geological Survey to study the geology, but principally the topography of the region and to learn among other things why the river took the peculiar course it does across the moun-

tains and plateaus of Texas. It may be classed as one of the great rivers of the country, as it is over 1,400 miles in length. It rises in the mountains of Colorado, where it is fed by the snows of the Rockies; but when it leaves the Rockies its course is across the desert, and for 1,400 miles only three streams feed it.

Mr. Hill discovered that one important source of supply in the canyon region was hundreds of hot springs which came up in the bed of the river and probably supplied one-third of the volume of the water. Another curious fact is, that for nine months of the year, at El Paso, Tex., it is a lost river; that is, the bed is dry until it is fed by the melting snows and rains from the mountains, when it is a roaring torrent. The region of the river explored by Mr. Hill was through an unknown country. His boats were made in Texas and transported many miles by rail and wagon to the river. His party of five consisted of his nephew, who served in the Cuban War, a trapper who knew parts of the country, and two adventurous Texans The expedition entered the river at Presidio Del Norte and traveled for several hundred miles until they reached the Pecos River. For many miles it is a canyon country with steep precipitous walls from 500 to 1,700 feet high, so that one is virtually a prisoner for many miles when he enters the river. And even at places where the plateau top can be reached, the arid desert stares them in the face.

To cross this waste to the nearest far-distant settlement without ample water and food means starvation, so the only alternative is to continue the journey when the start is made down the river. The river is full of rapids and cascades, and jagged rocks protrude above the foam and make navigation very dangerous—only strong and skilful boatmen can succeed. Not only this, but long portages must be made; so that after leaving Presidio two months elapsed before the branch known as the Pecos was reached. The scenery of these canyons is rugged and grand, even to one familiar with the grandest canyon and plateau scenery of Arizona and Utah. Enormous chalk cliffs were noted and frequent intercalated beds of lava were met with. In some places the river was so narrow and the walls of solid rock so high and precipitous that the sunlight could barely be seen 1,000 feet above. Mr. Hill has the credit of exploring a new section of country about which nothing was previously known. His report to the Government will be read with interest. Game was very abundant and plenty of black deer were shot. Ducks were plentiful and were an article of diet for a couple of weeks, until the expedition was surfeited, when no one could be tempted to eat them. A new species of Rocky Mountain sheep, different from the more northern neighbor, was discovered by the party.—*Oscar C. S. Carter.*

The American Electrochemical Society will hold its second general meeting at Niagara Falls, N. Y., beginning Monday, September 15th, and extending to the 17th, or possibly to the 18th. The local committee will provide interesting excursions and exhibitions of the local electrochemical industries, which will be an important feature of the meeting. A number of important papers are already promised, and the prospects are that the meeting will be even more successful than the inaugural meeting at Philadelphia. Entertainment will be provided for ladies.